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A COMPILATION OF SPACECRAFT LOADS DATA
FROM
FOUR TITAN CENTAUR LAUNCH VEHICLE FLIGHTS
VOLUME IV
TITAN STAGE I & CENTAUR FIRST BURN OSCILLATIONS

Compiled by George Kachadourian

(NASA-CR-144947-Pt-1) A COMPILATION OF
SPACECRAFT LOADS DATA FROM FOUR TITAN
CENTAUR LAUNCH VEHICLE FLIGHTS. VOLUME 4,
PART 1: TITAN STAGE 1 AND CENTAUR FIRST
BURN OSCILLATIONS (General Electric Co.)

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January 1977

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16. Abstract The payloads carried by the first four Titan Centaur Launch Vehicle flights were a Viking Dynamic Simulator, the Helios A Spacecraft and the two Viking Spacecraft. Dynamic loads data were gathered by the NASA Viking Project Office from these four flights for applications to the Viking Spacecraft. This volume contains time histories and Power Spectral Density analyses of Vibration & Strain data from periods of Titan Stage I flight where First Longitudinal Mode oscillations were evident in flight of TC-1, TC-4 and TC-3. Time history and PSD data is also presented showing the character of the oscillations during Centaur First Burn for TC-4 and TC-3.					
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A COMPILATION OF SPACECRAFT LOADS DATA
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January 1977

ABSTRACT

The payloads carried by the first four Titan Centaur Launch Vehicle Flights were, a Viking Spacecraft Dynamic Simulator, the Helios-1 spacecraft and the two Viking Spacecraft. Dynamic loads data was accumulated by the NASA Viking Project Office from these four flights for application to the Viking Spacecraft. This report contains a compilation of that data and is presented for reference and information. The data has been compiled into the following five volumes:

- Volume I - Acoustic Data - NASA CR-144944
- Volume II - Vibration Power Spectral Density Data - NASA CR-144945
- Volume III - Shock Spectra of Transients - NASA CR-144946
- Volume IV - Titan Stage I and Centaur Burn Oscillation- NASA CR-144947
- Volume V - Time History Plots - NASA CR-144948

VOLUME IV

TITAN STAGE 1 AND CENTAUR FIRST BURN OSCILLATIONS

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2. TC-4 Data	2.1 - 2.55b	2.1 - 2.113
3. TC-3 Data	3.1 - 3.63b	3.1 - 3.130

Notations Used in Volume IV

Bus -	Major structural assembly of Viking Orbiter - See Figure 3.1, page 2.6
Max Q -	Period of launch flight of maximum dynamic pressure.
PFLA -	Proof Flight Lander Adapter; a ruggedized version of the Viking VLCA
POGO -	Longitudinal oscillations during Titan Stage 1 Burn involving propulsion system and structural system coupling
PSD -	Power spectral density, vibration, g^2 /Hertz
VDS -	Viking Dynamic Simulator, TC-1 payload
VLC -	Viking Lander Capsule
VLCA -	Viking Lander Capsule Adapter
VO -	Viking Orbiter
VS/C -	Viking Spacecraft
V-S/C-A -	Viking Spacecraft Adapter
TC-1 -	The Titan Centaur Launch Vehicle Number 1
TC-2 -	The Titan Centaur Launch Vehicle Number 2, Helios Spacecraft

Notations Used in Volume IV (continued)

- TC-3 - The Titan Centaur Launch Vehicle Number 3, Second Viking Spacecraft Launch
- TC-4 - The Titan Centaur Launch Vehicle Number 4, First Viking Spacecraft launch.

Transformation Notation

- XDDL = X acceleration of Lander c. g.
- YDDL = Y acceleration of Lander c. g.
- ZDDL = Z acceleration of Lander c. g.
- ZDDB = Z acceleration at the base of the Lander Adapter

Description of Contents: Summary Data from Titan Stage 1 Burn and Centaur
First Burn Oscillation

This volume presents Power Spectral Density (PSD) analyses and associated time history plots from TC-1, TC-4 and TC-3 during two periods of flight where oscillatory motions are wont to occur. The TC-1 data is of the period of maximum POGO amplitude. The TC-4 and TC-3 data is of several periods of time during Stage 1 burn and Centaur Main Engine first burn. The data is presented to provide a measure of amplitudes and frequency content of oscillations during these periods of flight.

The summary data, presented for the two Viking flights only, are envelopes of longitudinal oscillations during Titan Stage 1 Burn and lateral oscillations during Centaur Burn. Each gives the maximum PSD levels and frequency content for oscillation at the Viking Lander center of gravity. Longitudinal oscillations during the Titan Stage 1 Burn at the base of the Lander Adapter are also presented in summary.

POWER SPECTRAL DENSITY

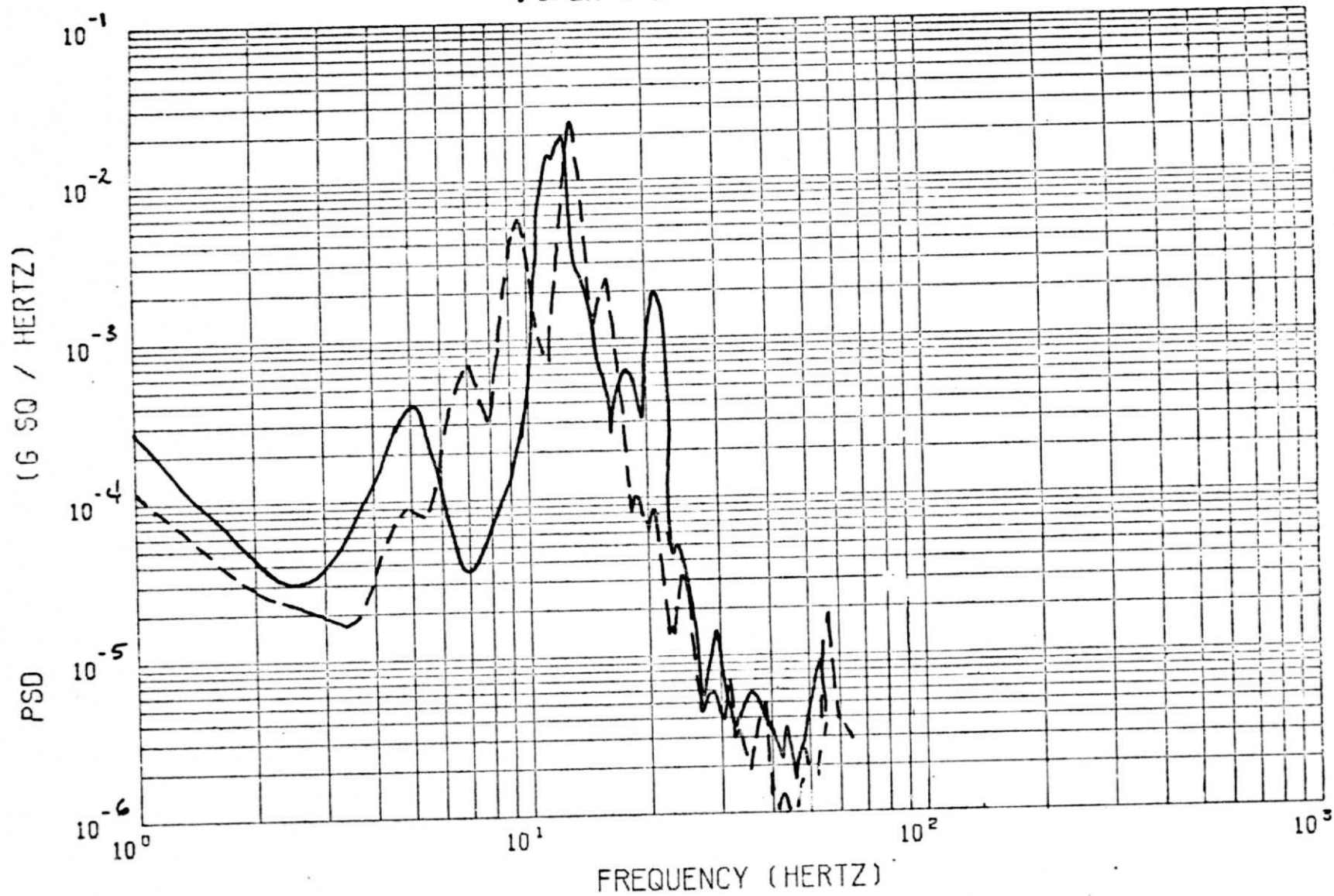


Figure 0.1 Summary, Stage 1 Burn Data, ZDDL

—— TC-4
 ---- TC-3

2.0
PSD
(G SQ / HERTZ)

POWER SPECTRAL DENSITY

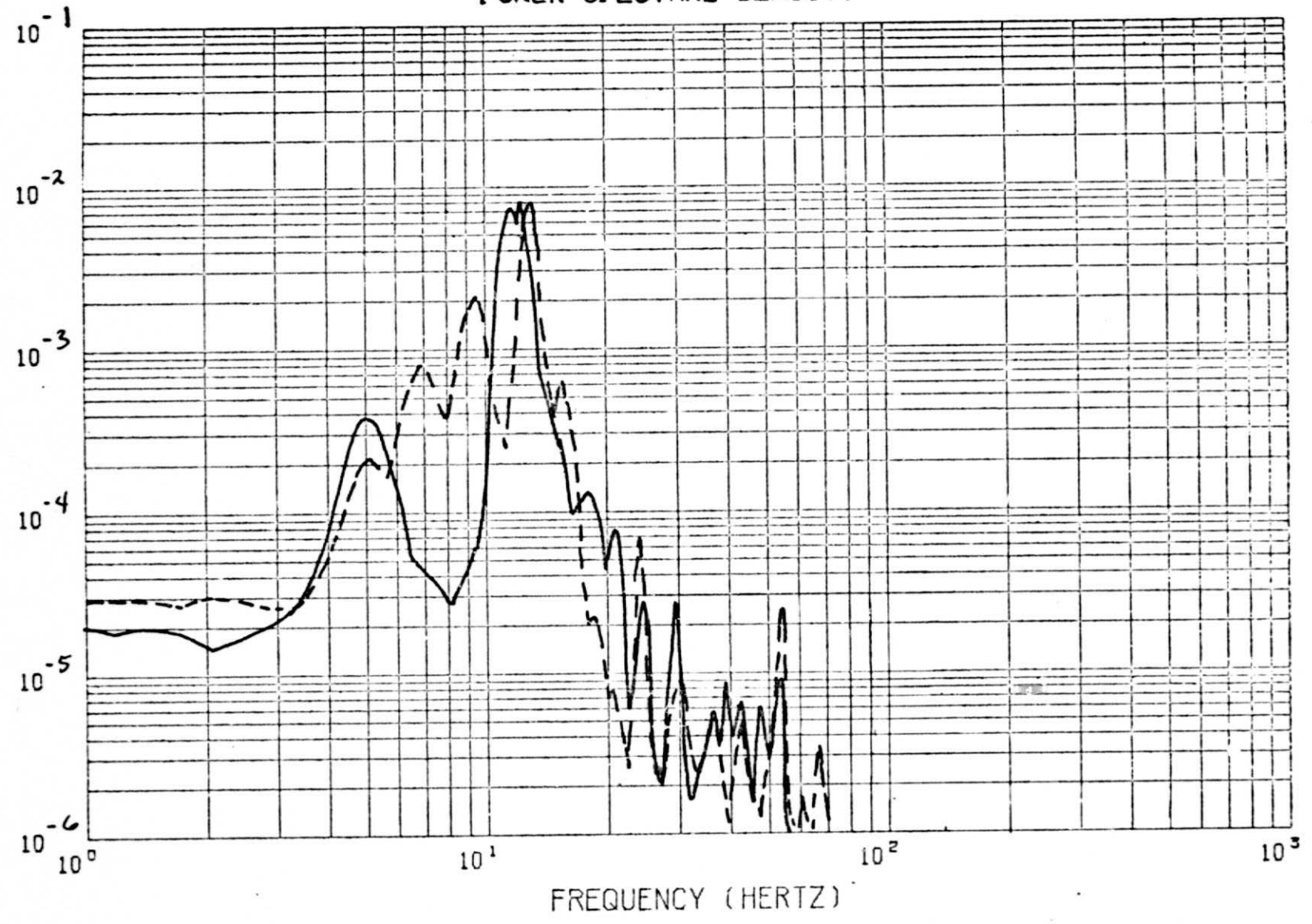


FIGURE 0.2 SUMMARY, Stage 1 Burn, ZDDB

—— TC-4
---- TC-3

POWER SPECTRAL DENSITY

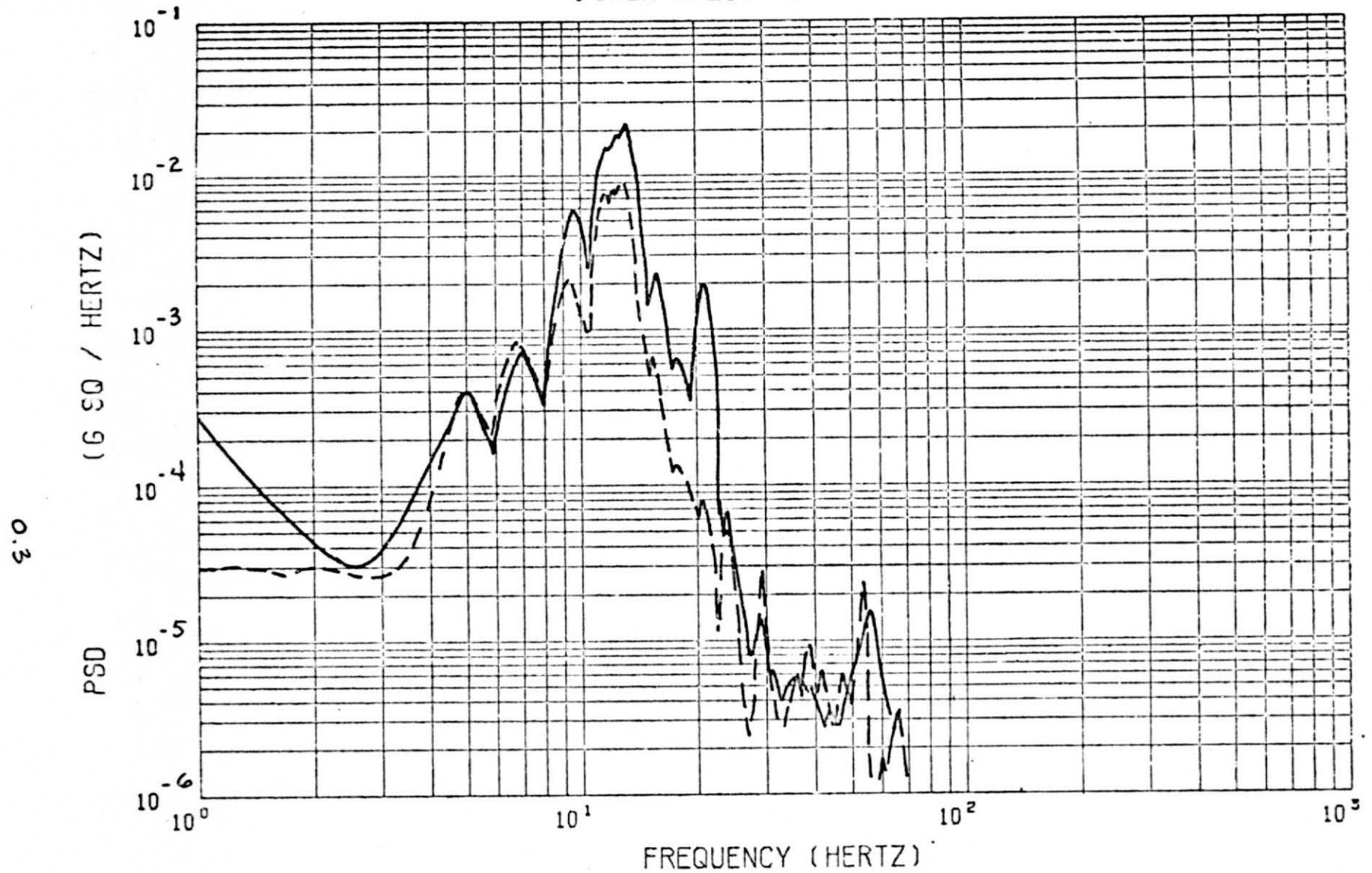


Figure 0.3 Summary, Stage 1 Burn, TC-4 & TC-3

— ZDDL
 - - - Zddb

POWER SPECTRAL DENSITY

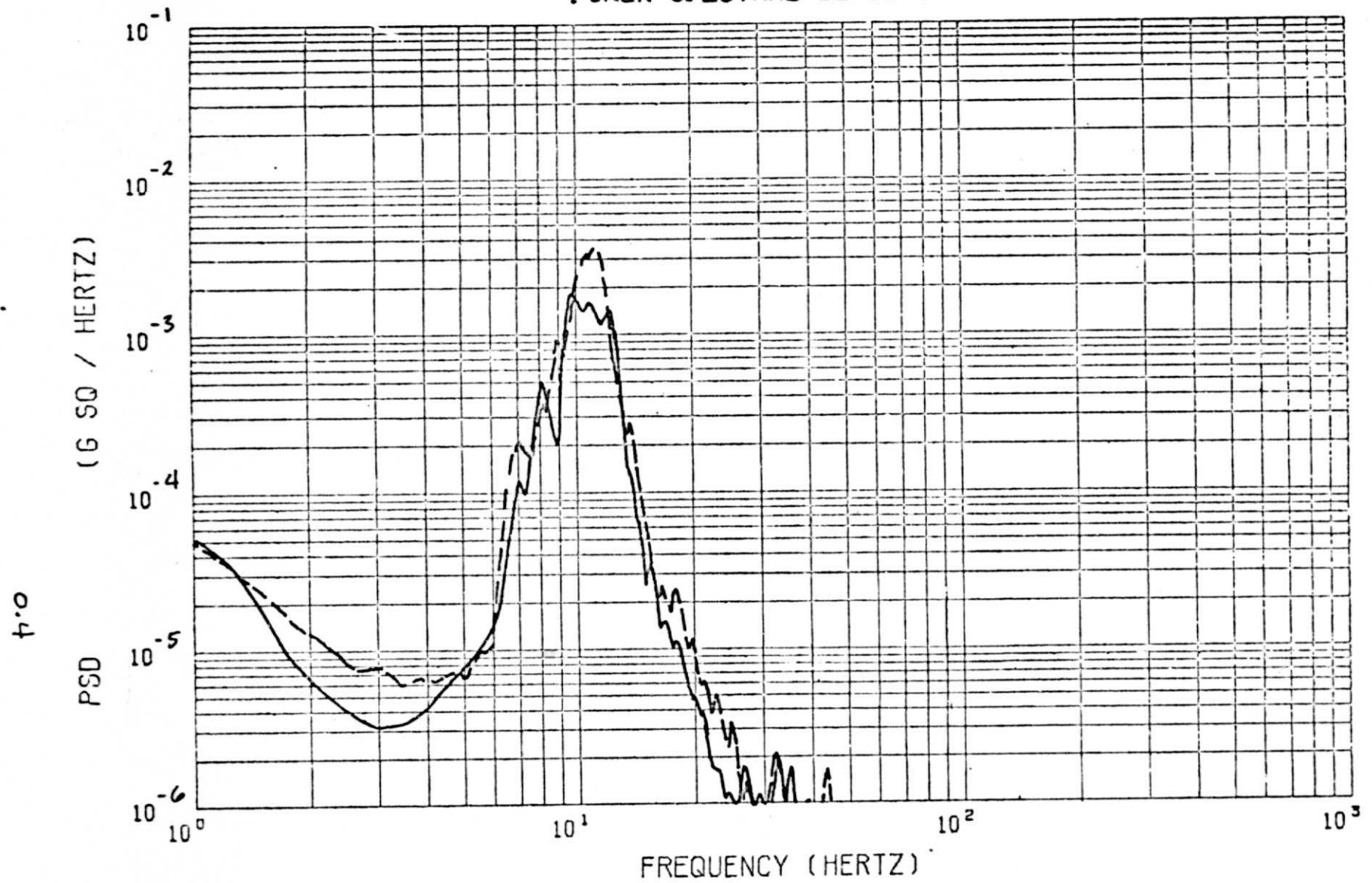


Figure 0.4 Summary, Centaur First Burn Data YDDL

— TC-4
 --- TC-3

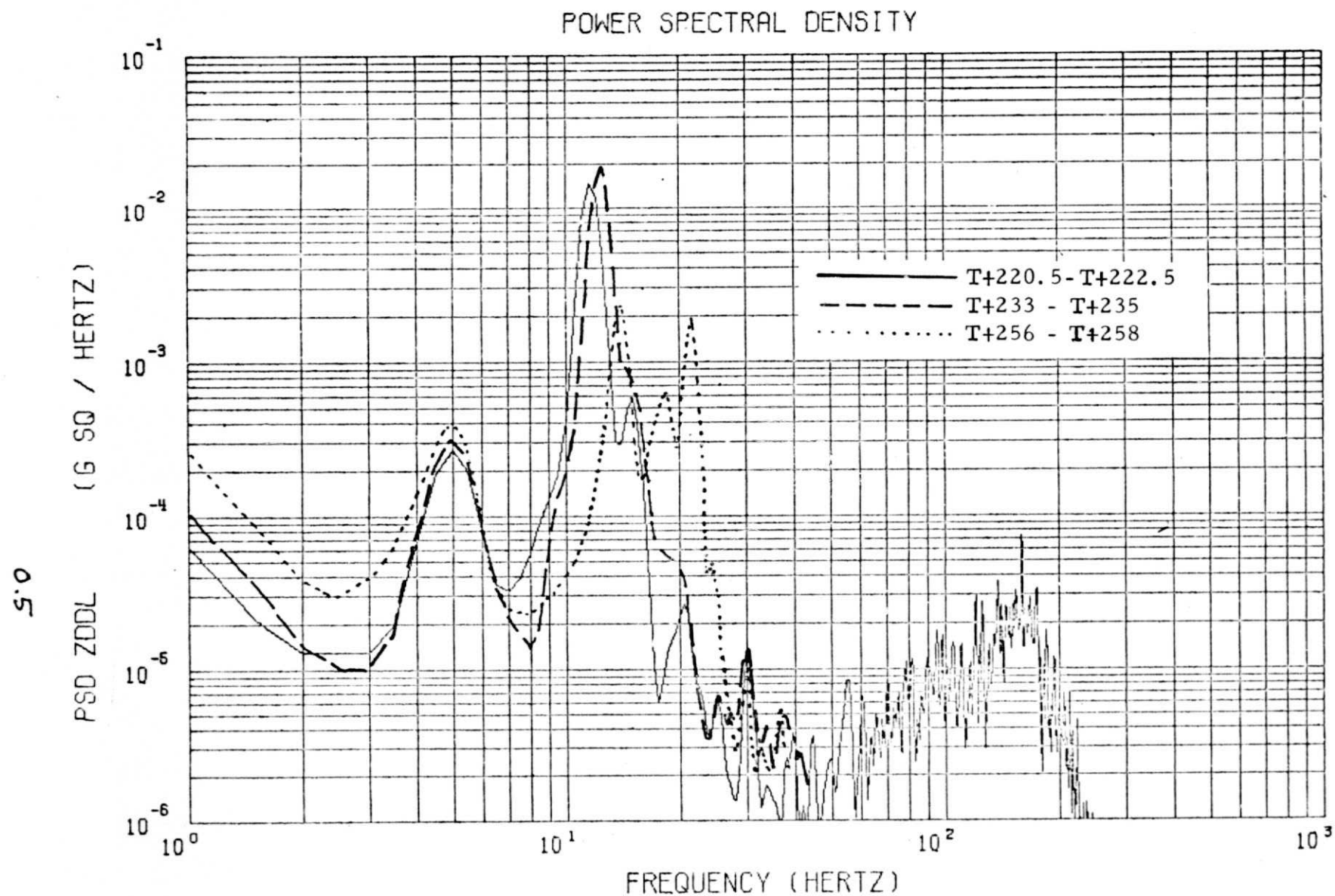


Figure 0.5 TC-4 Summary of Stage 1 Burn Data, ZDDL

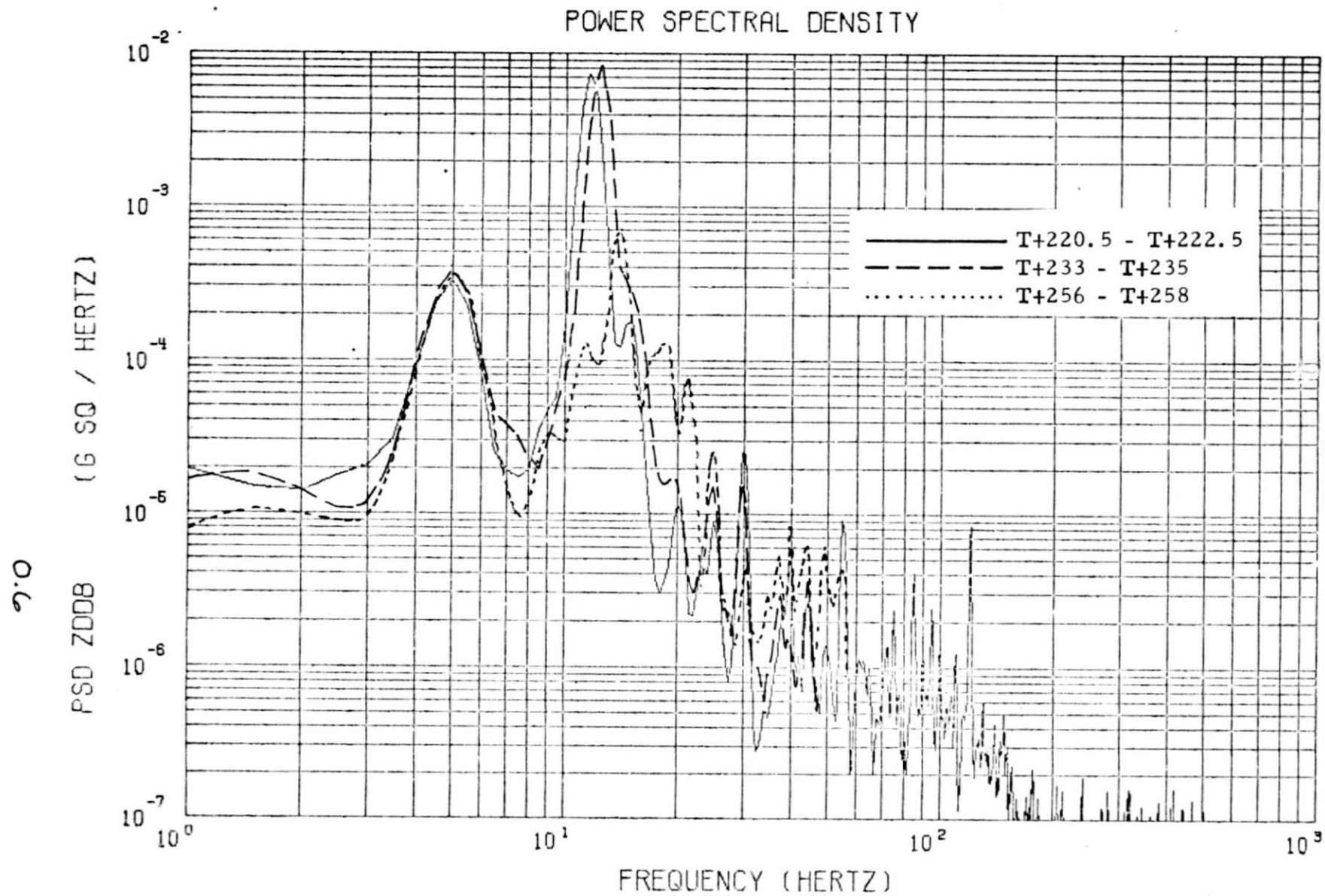


Figure 0.6 TC-4 Summary of Stage 1 Burn Data - ZDDB

0.7

PSD ZDDL (G² / HERTZ)

POWER SPECTRAL DENSITY

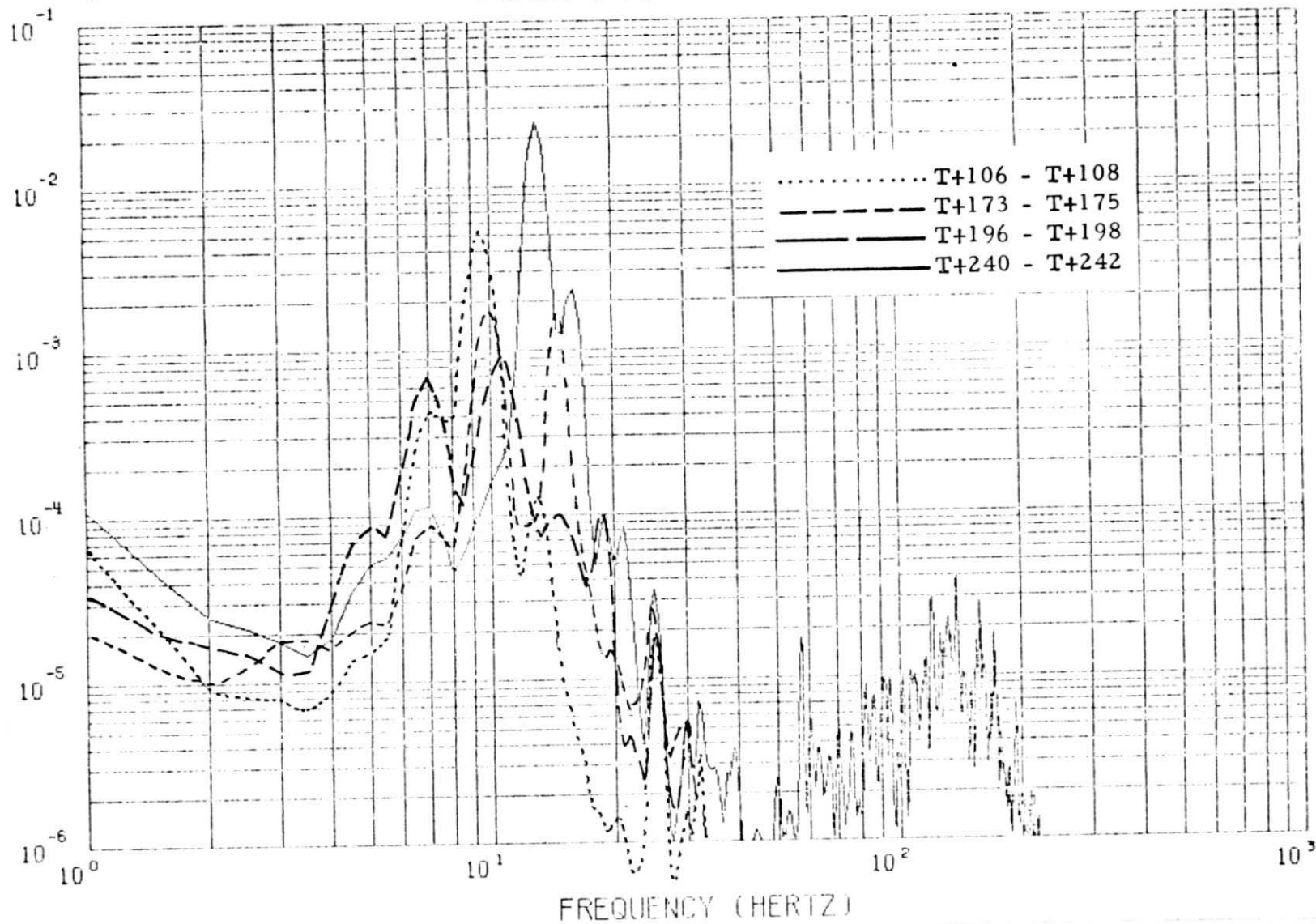


Figure 0.7. TC-3 Summary of Stage 1 Burn Data ZDDL

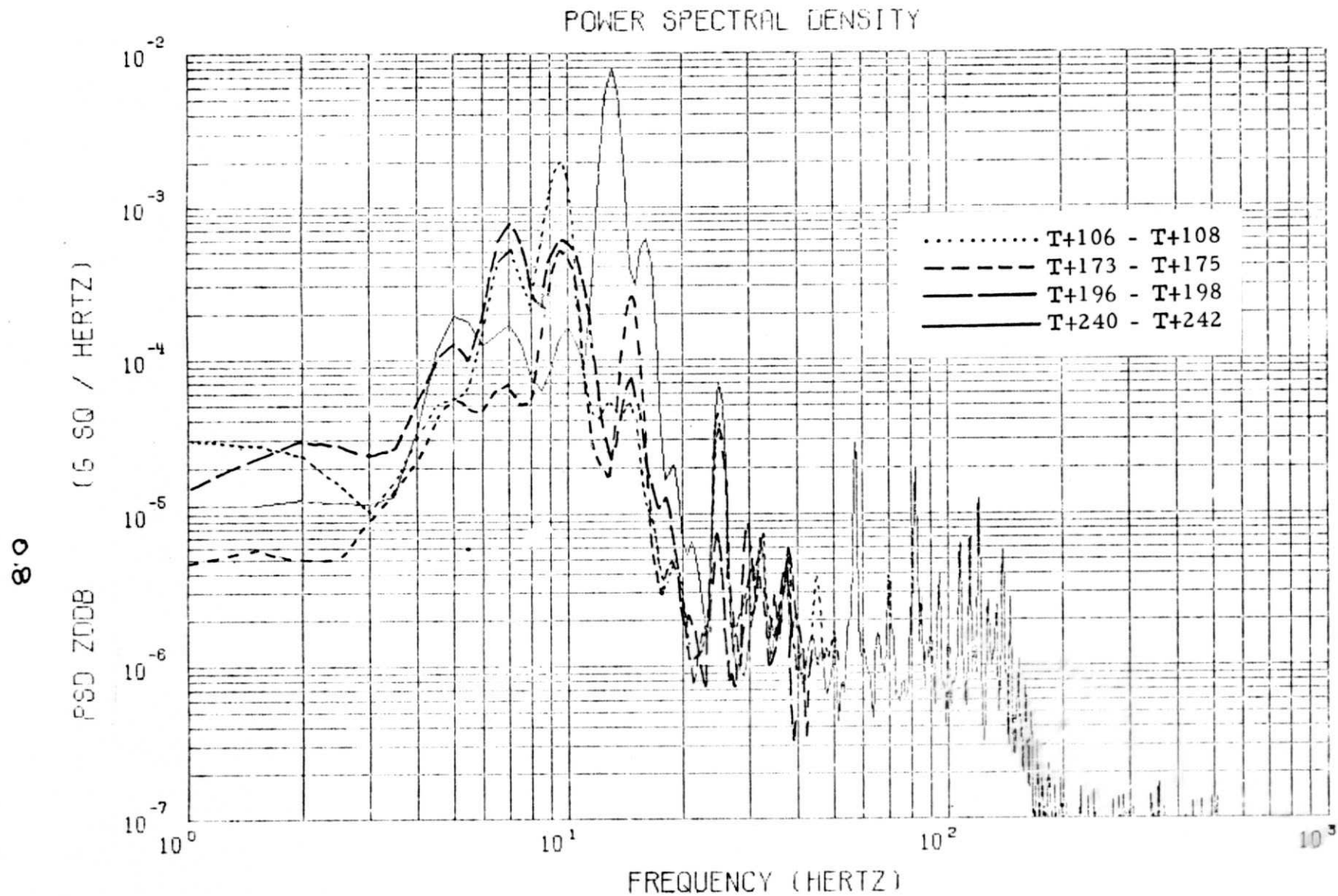


Figure 0.8-TC-3 Summary of Stage 1 Burn Data - ZDDB

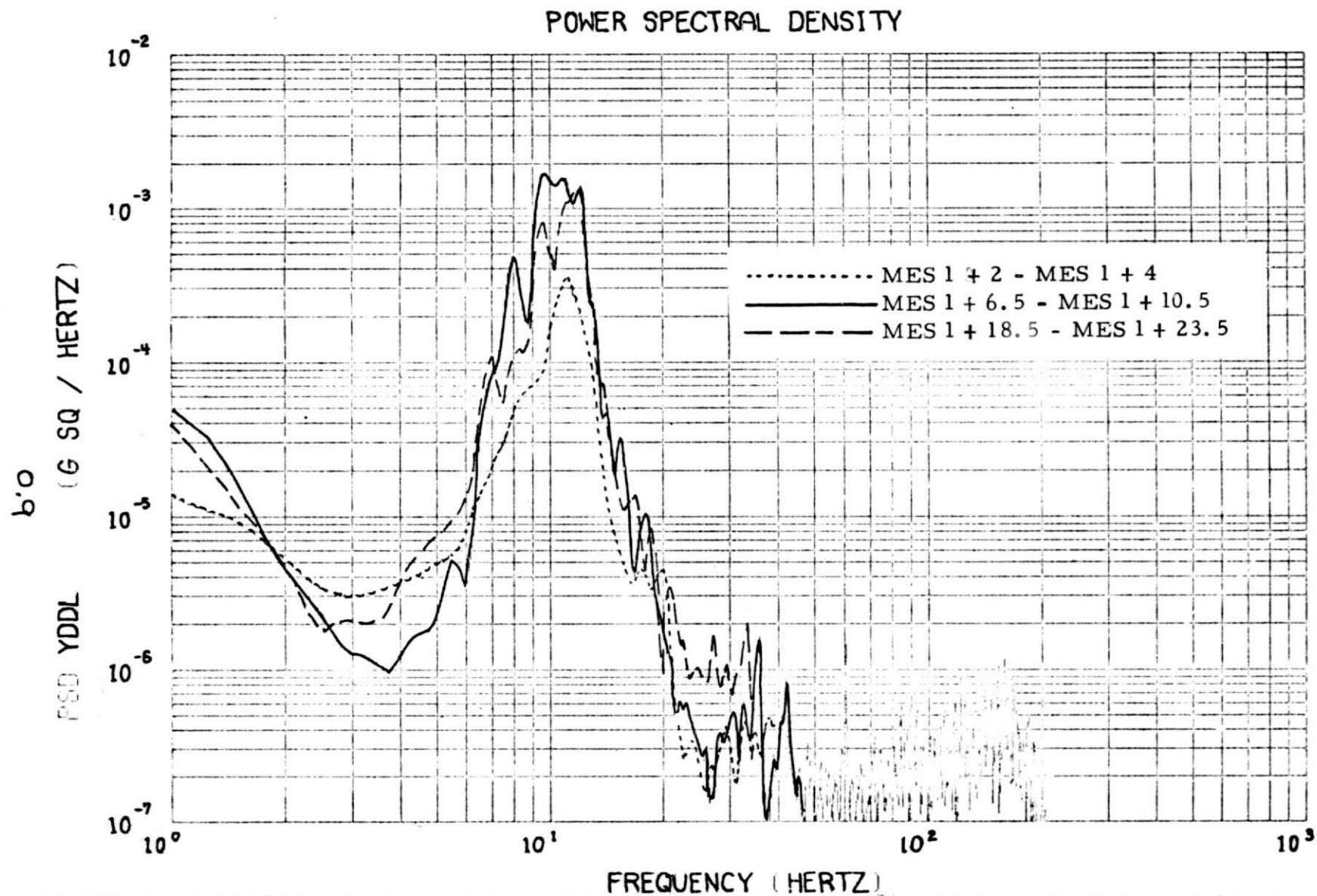


Figure Q9-TC-4 Summary of Centaur Burn Data, YDDL

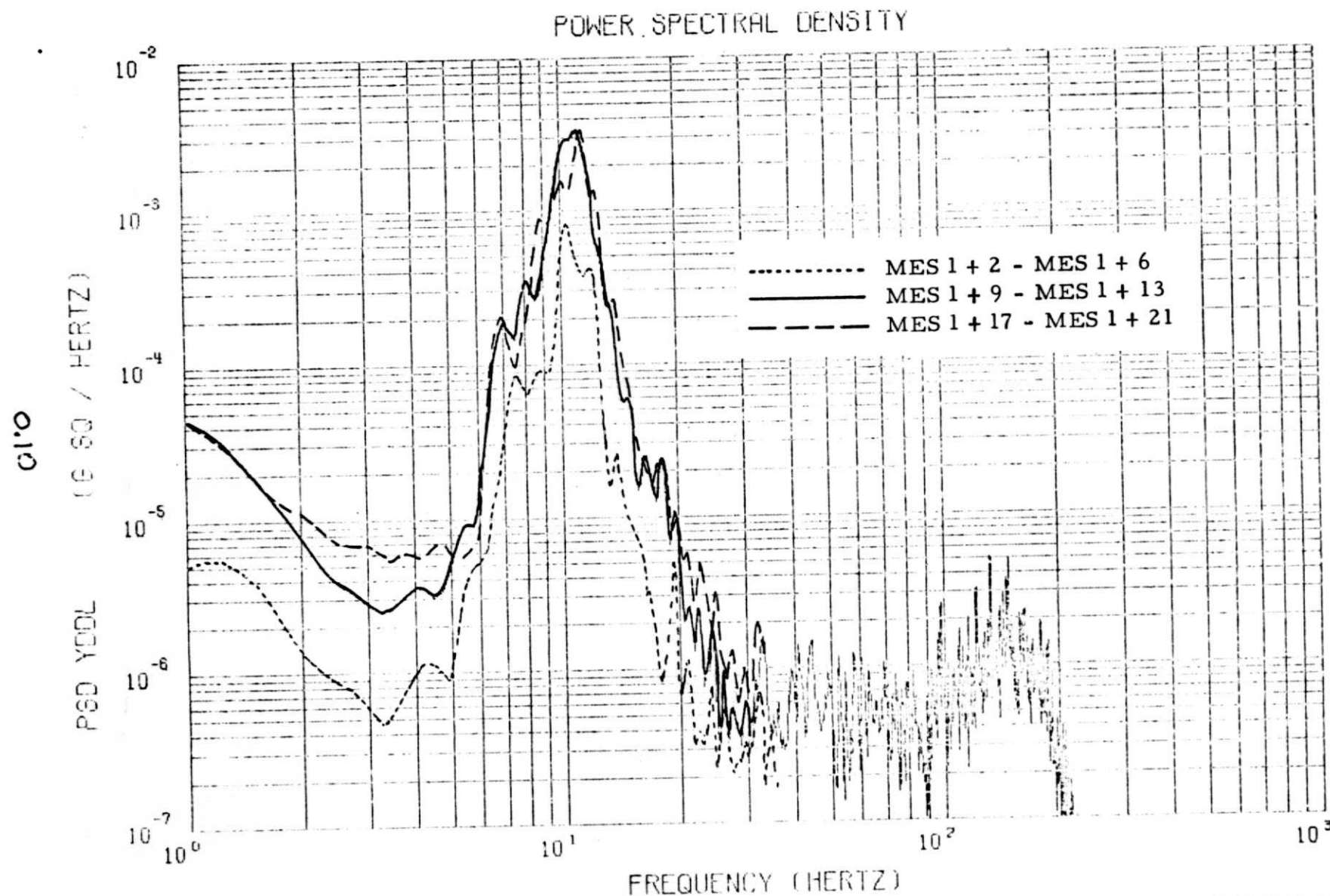


Figure 0.10 - TC-3 Summary of Centaur Burn Data, YDDL

ORIGINAL PAGE IS
OF POOR QUALITY

VOLUME IV

TITAN STAGE 1 AND CENTAUR FIRST BURN OSCILLATIONS

Section 1

TC-1 TITAN CENTAUR PROOF FLIGHT DATA
(VIKING DYNAMIC SIMULATOR)

Launch Data February 12, 1974

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1.2a-1.7b PSD's of Forces & Moments at the Base of the Lander Adapter	1.6-1.17
1.8a-1.13b PSD's of VLC cg Accelerations	1.18-1.29

Description of Contents - Section 1: TC-1 Flight Data, Stage 1
Longitudinal Oscillations

This section presents time histories and PSD's of forces and moments at the base of the Proof Flight Lander Adapter (PFLA) and of accelerations of the Lander c.g. The data was obtained through transformation of the strain measurements on the PFLA assuming a rigid lander. These data were generated in a practice exercise in preparation for the Viking flights. Additional data and its exposition is presented in Reference 1.

The data presented here is for the two second period of maximum acceleration amplitude of the POGO oscillation. This time was from 13:51:58 to 13:52:00 GMT or T+236.4 to T+238.4 from Stage 0 Ignition or T+121.3 to T+123.3 from Stage 1 Ignition.

Parameters for Which PSD Analysis is Presented

Parameter	Description
FX FY FZ MX MY MZ	Forces and moments at the base of the Lander Adapter transformed from the Adapter strain measurements
$\ddot{X}$ $\ddot{Y}$ $\ddot{Z}$ $\ddot{\theta}_X$ $\ddot{\theta}_Y$ $\ddot{\theta}_Z$	Lander c.g. accelerations obtained from transformation of Lander Adapter strain measurements

Parameters for which PSD Analysis is Presented,

Parameter	Description
F_X F_Y F_Z M_X M_Y M_Z	Forces and moments at the base of the Landor Adapter transformed from the Adapter strain measurements
$\ddot{X}$ $\ddot{Y}$ $\ddot{Z}$ $\ddot{\theta}_x$ $\ddot{\theta}_y$ $\ddot{\theta}_z$	Landor c.g. accelerations obtained from transformation of Landor Adapter strain measurements

Table 1.1 VDS MEASUREMENT LIST CENTAUR FM/FM #2 2215.5 MHz

VCO Number	Measure- ment Number	Description	Zero Load Bias	Full Scale Range	Filter Cutoff Frequency (Hz)	
					A	B
3	CY216-S	V-S/C-A Axial Load Transducer	59%	25342 lbs	—	—
4	CY215-S	V-S/C-A Axial Load Transducer	59%	25331 lbs	—	—
5	CY208-φ	VODS Sprung Mass Z-Axis Accelerometer	20%	10.01 g's	—	—
6	CY207-φ	VODS Bus X-Axis Accelerometer	50%	10.00 g's	—	—
7	CY206-φ	VODS Bus Y-Axis Accelerometer	50%	9.99 g's	—	—
8	CY205-φ	VODS Bus Y-Axis Accelerometer	50%	10.01 g's	45	90
9	CY204-φ	VODS Bus Z-Axis Accelerometer	50%	20.00 g's	200	118
10	CY203-φ	VODS Bus Z-Axis Accelerometer	50%	19.98 g's	180	162
11	CY202-φ	VODS Bus Z-Axis Accelerometer	50%	20.00 g's	160	—
12	CY214-S	PFLA Truss Axial Load, Member 202	59.6%	27177 lbs	153	—
13	CY213-S	PFLA Truss Axial Load, Member 203	61.0%	27192 lbs	145	—
14	CY212-S	PFLA Truss Axial Load, Member 204	61.1%	27157 lbs	140	—
15	CY211-S	PFLA Truss Axial Load, Member 205	59.2%	26636 lbs	137	—
16	CY210-S	PFLA Truss Axial Load, Member 206	60.1%	27175 lbs	135	—
17	CY209-S	PFLA Truss Axial Load, Member 201	61.6%	27319 lbs	134	—
18	CY201-φ	Piezoelectric Accelerometer, Z-Axis	50%	40.0 g's	133	2100
19	CY217-Y	Acoustic Microphone	50%	150.0 dB	—	2800
CENTAUR FM/FM #1 2208.5 MHz						
19	CA886Y	Acoustic Microphone wd Equip Comp	50%	150.0 db	—	—

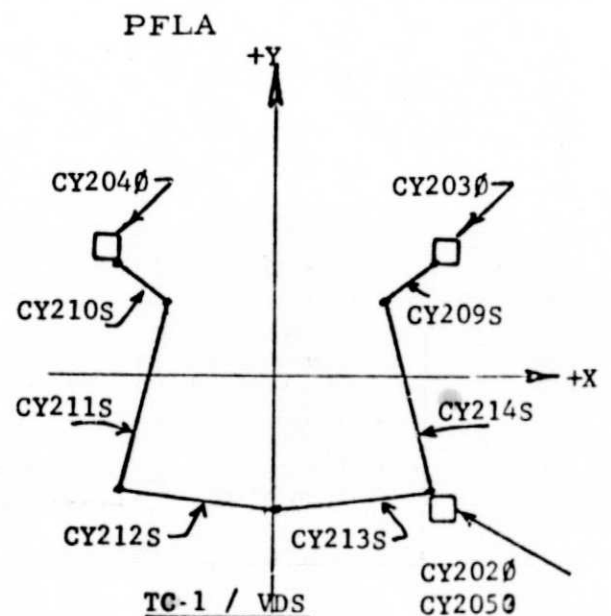
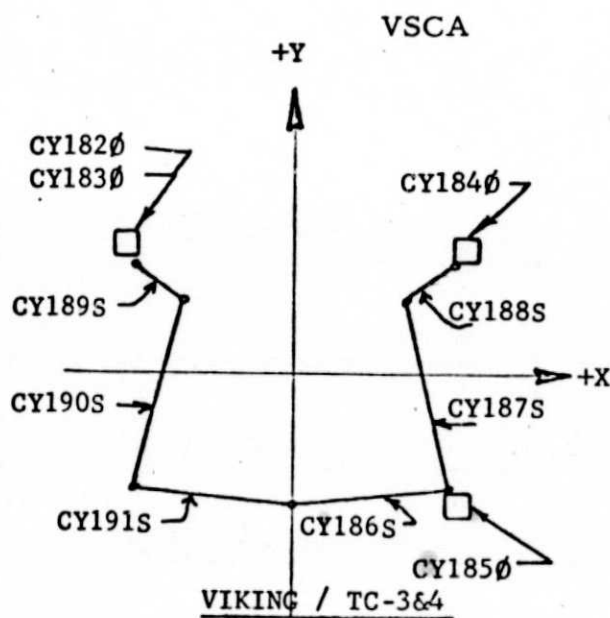
A. Filter set used with 1024 sps digitization rate. Design for minimum phase error (below 40 Hz) between channels 9 through 18.

B. Filter set used with 8192 sps digitization = double standard IRIG

Table 1.2

MEASUREMENTS CORRESPONDENCE
VIKING SPACECRAFT TO VDS

VIKING (TC-4 & 3)		VDS (TC-1)	
IRIG NO.	SENSOR		IRIG NO.
9	CY191S	↔	CY212S 14
10	CY190S	↔	CY211S 15
11	CY189S	↔	CY210S 16
12	CY188S	↔	CY209S 17
13	CY187S	↔	CY214S 12
14	CY186S	↔	CY213S 13
15	CY185Ø	↔	CY201Ø 18
16	CY184Ø	↔	CY203Ø 10
17	CY183Ø	↔	CY205Ø 8
18	CY182Ø	↔	CY204Ø 9



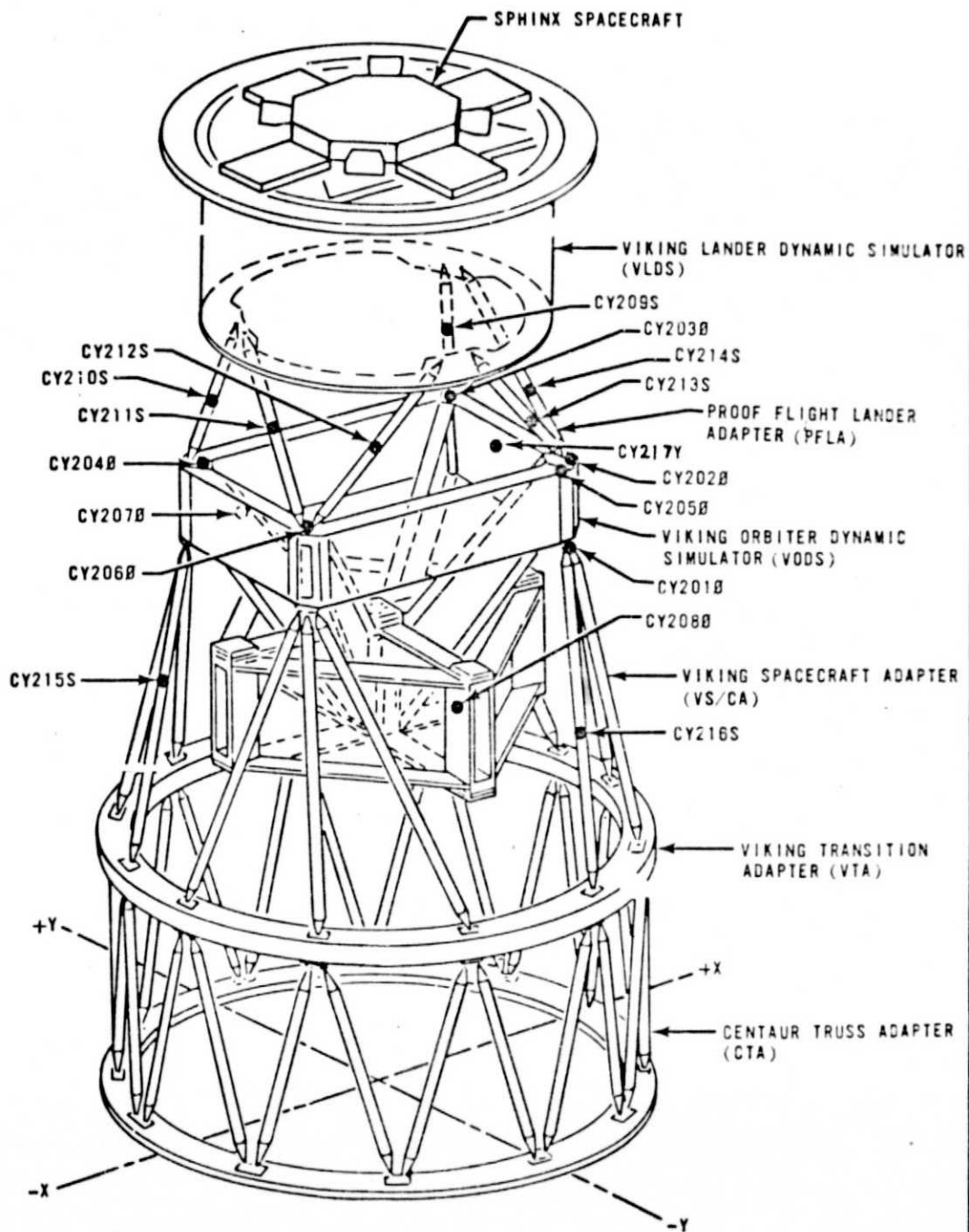


Figure 1.1 Viking Dynamic Simulator Instrumentation

1.6

SERIAL NUMBER = 0
FRAME 7
2054 INPUT DATA POINTS

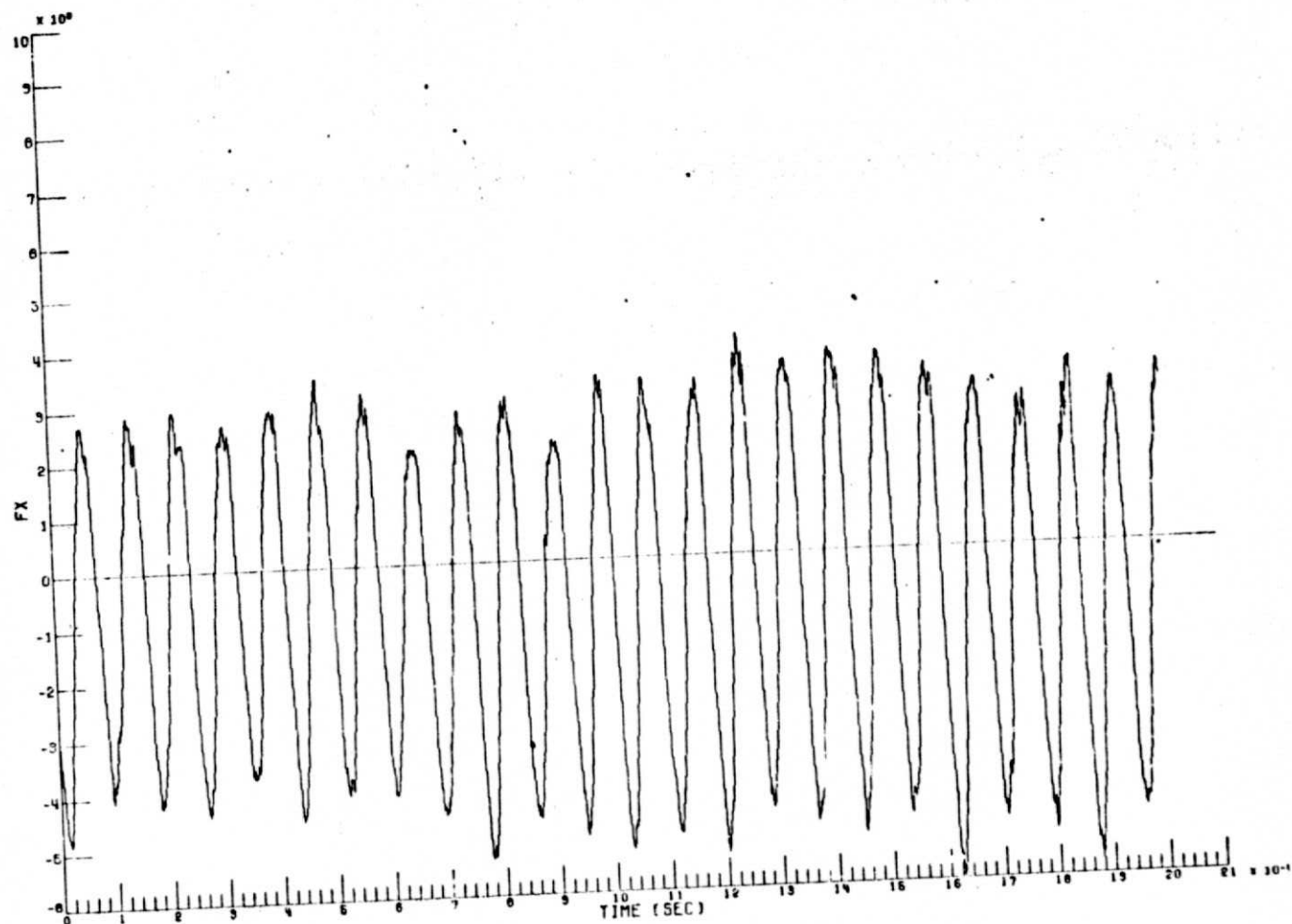
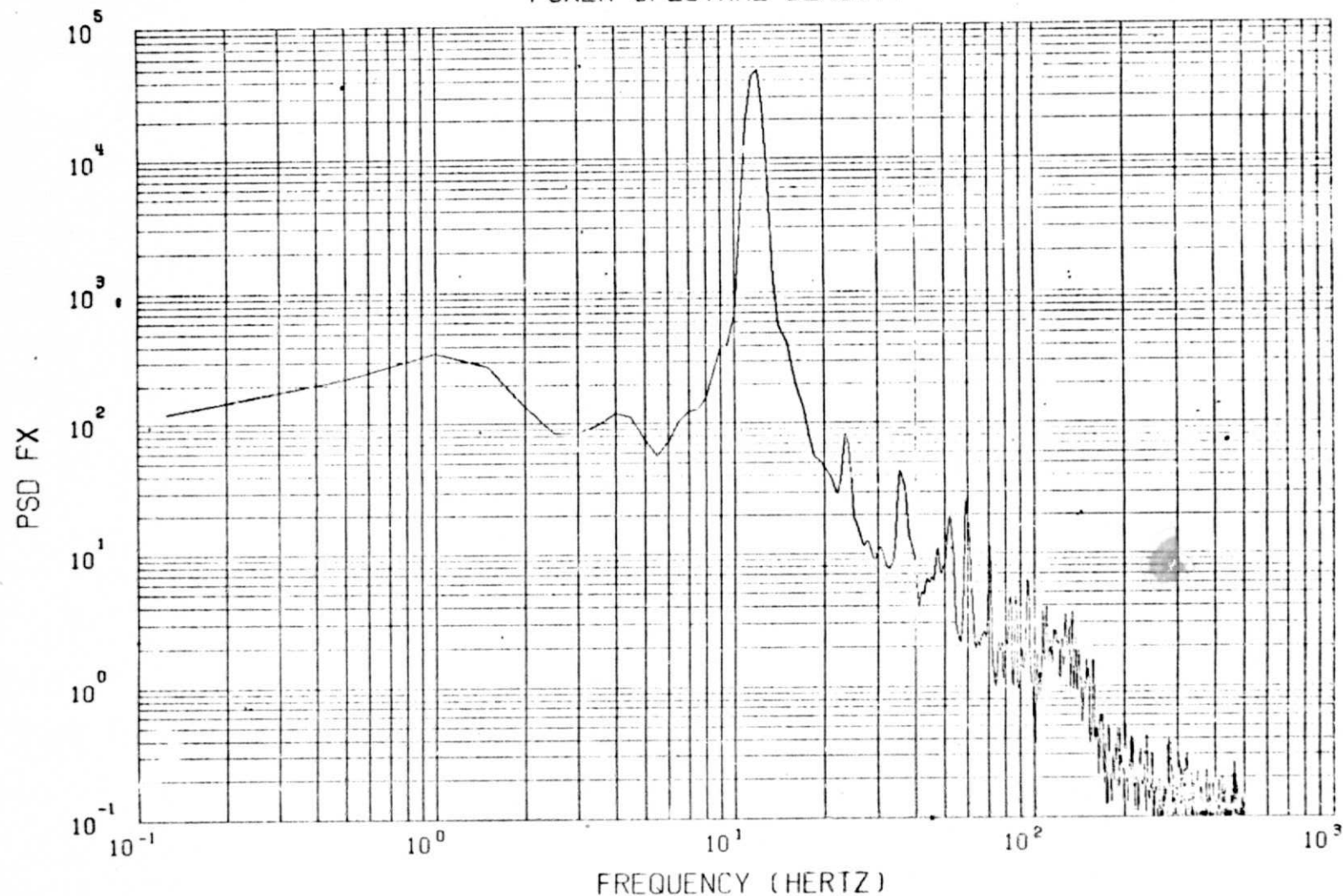


Figure 1.2a. TC-1 Max POGO - FX

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 8

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.2b - Max POGO - FX PSD

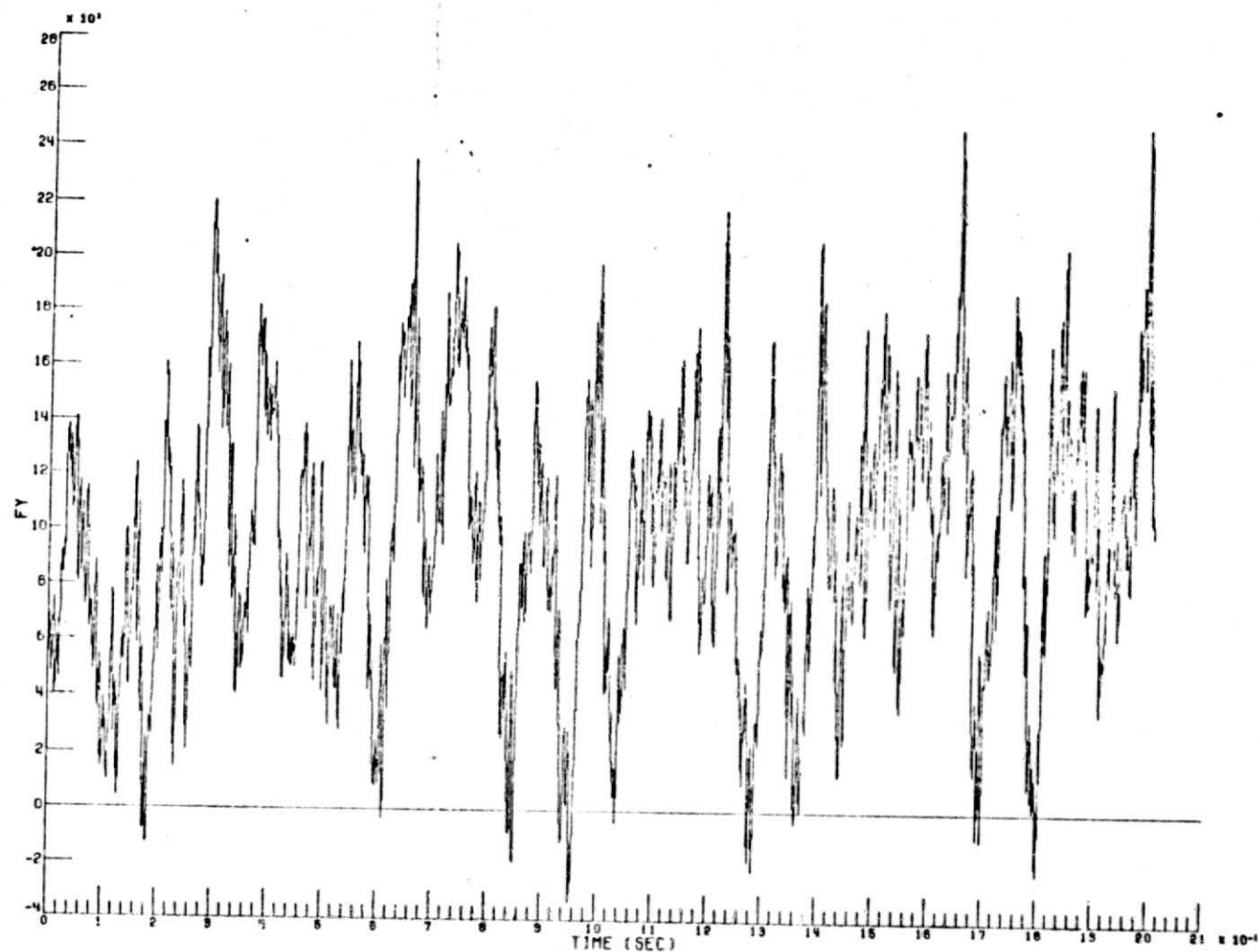
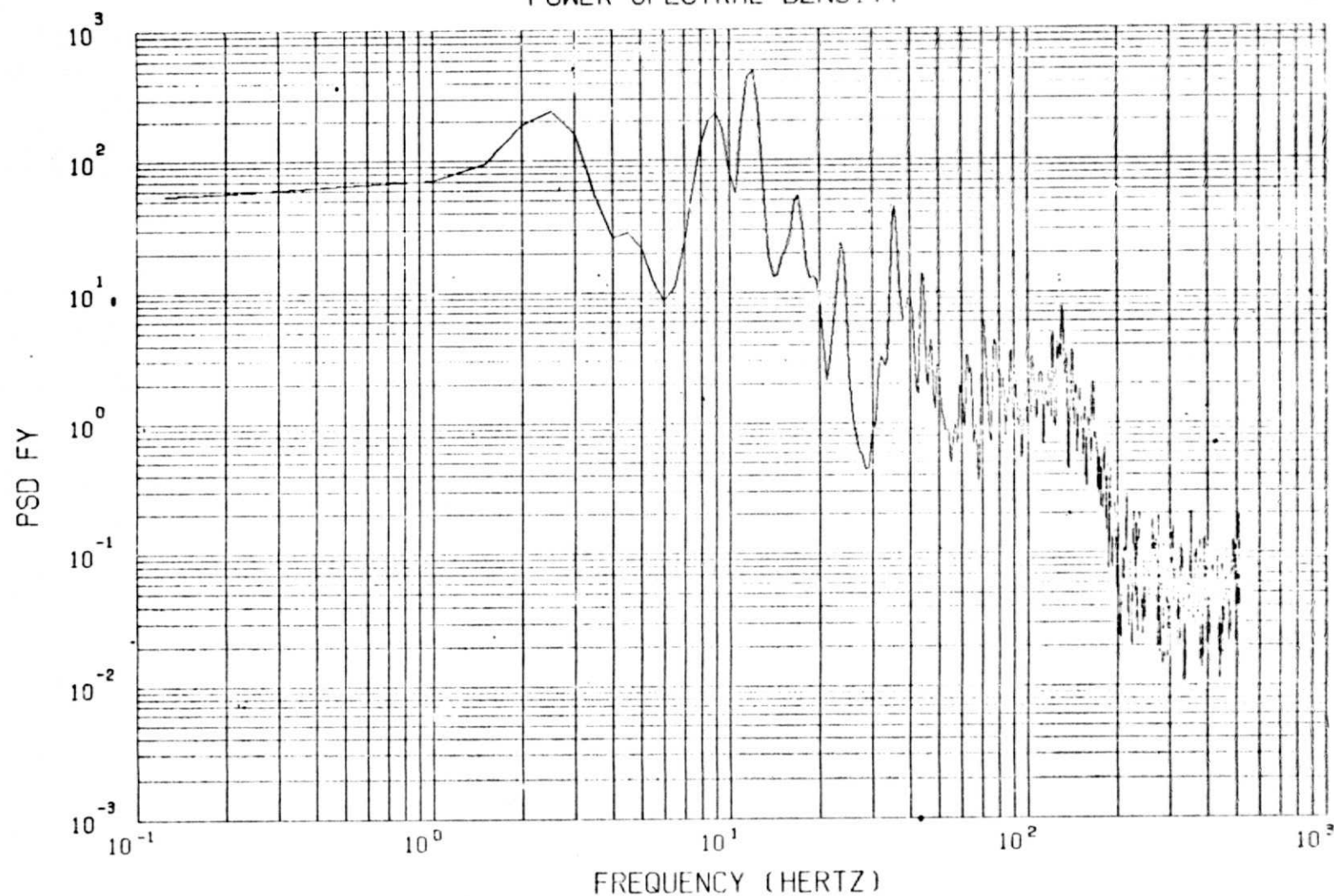


Figure 1.3a. TC-1 Max POGO - FY

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 16

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.3b. TC-1 Max POGO - FY PSD

1.10

SERIAL NUMBER = 0

FRAME 23

2054 INPUT DATA POINTS

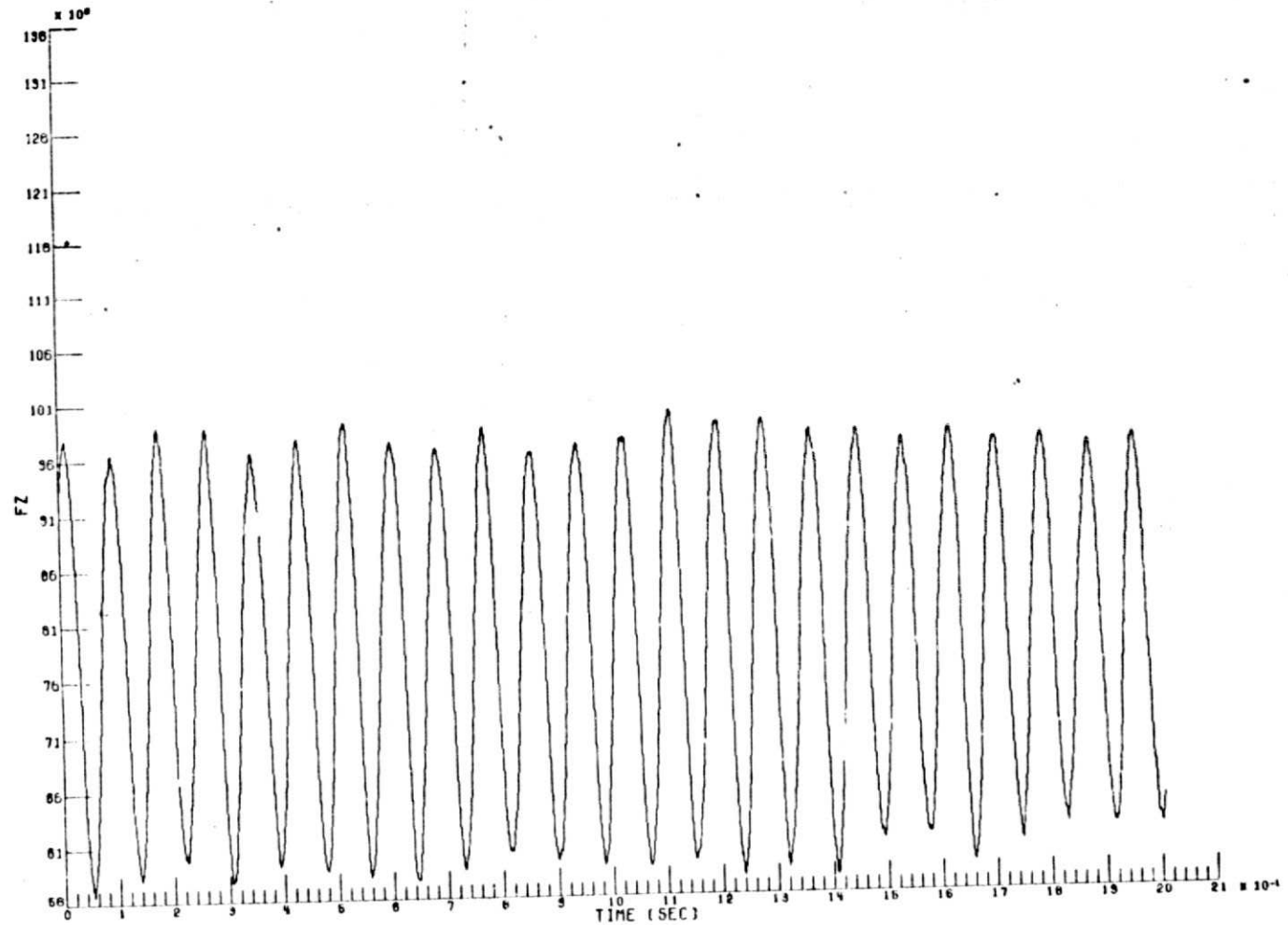
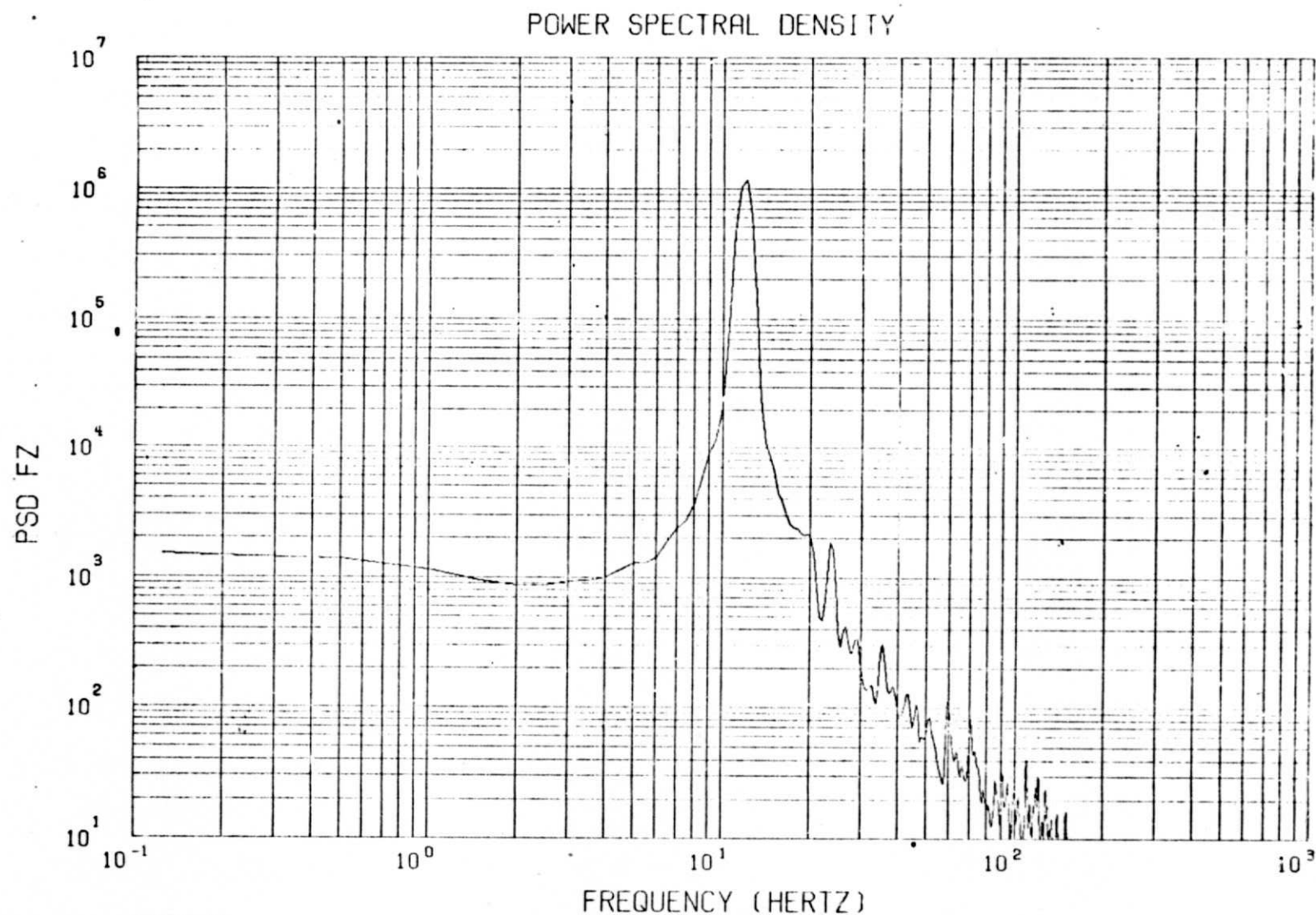


Figure 1.4a. TC-1 Max POGO - FZ



FRAME 24

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.4b. TC-1 Max POGO - FZ PSD

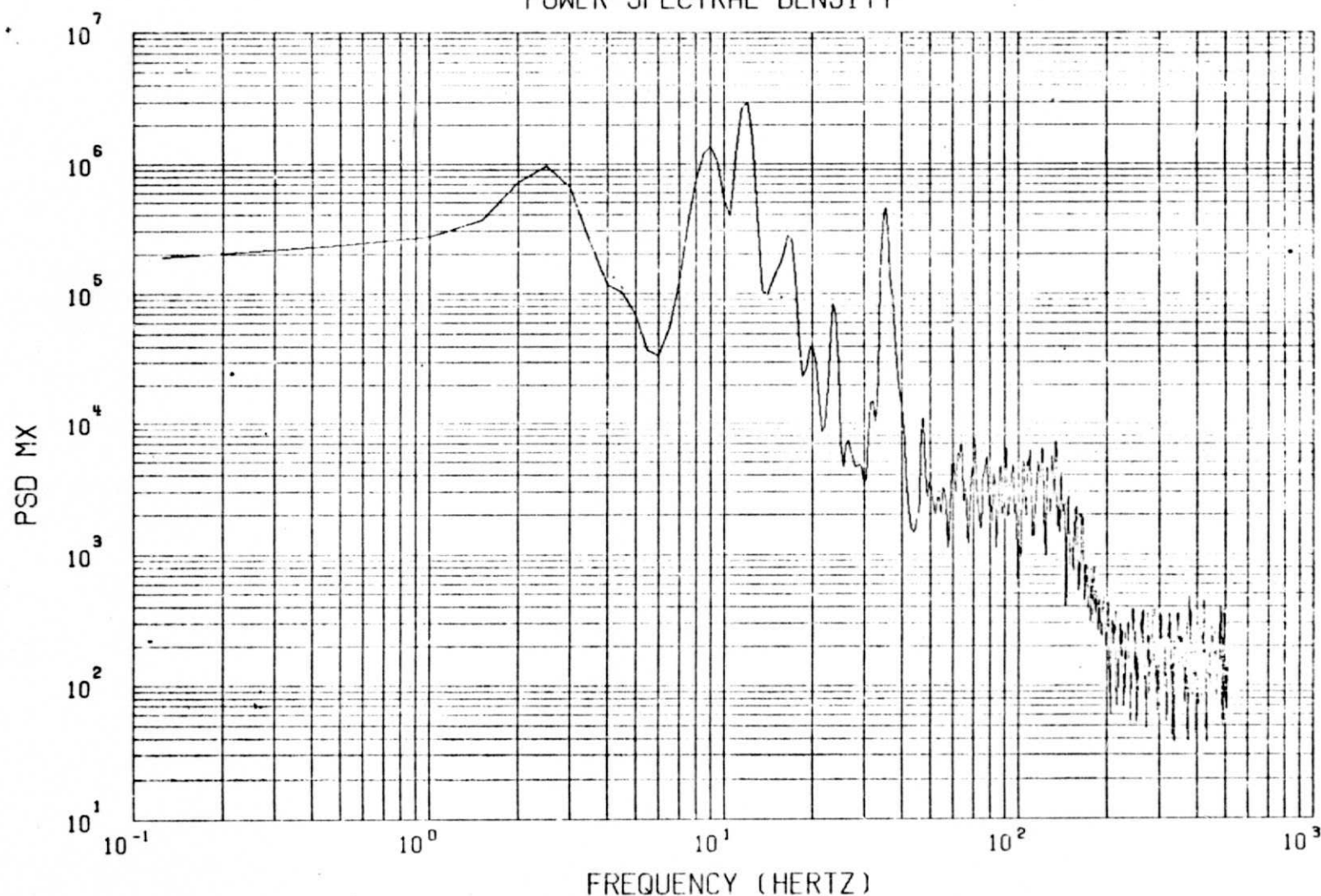
1.12

Figure 1.5a. TC-1 Max POGO - MX

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 32

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

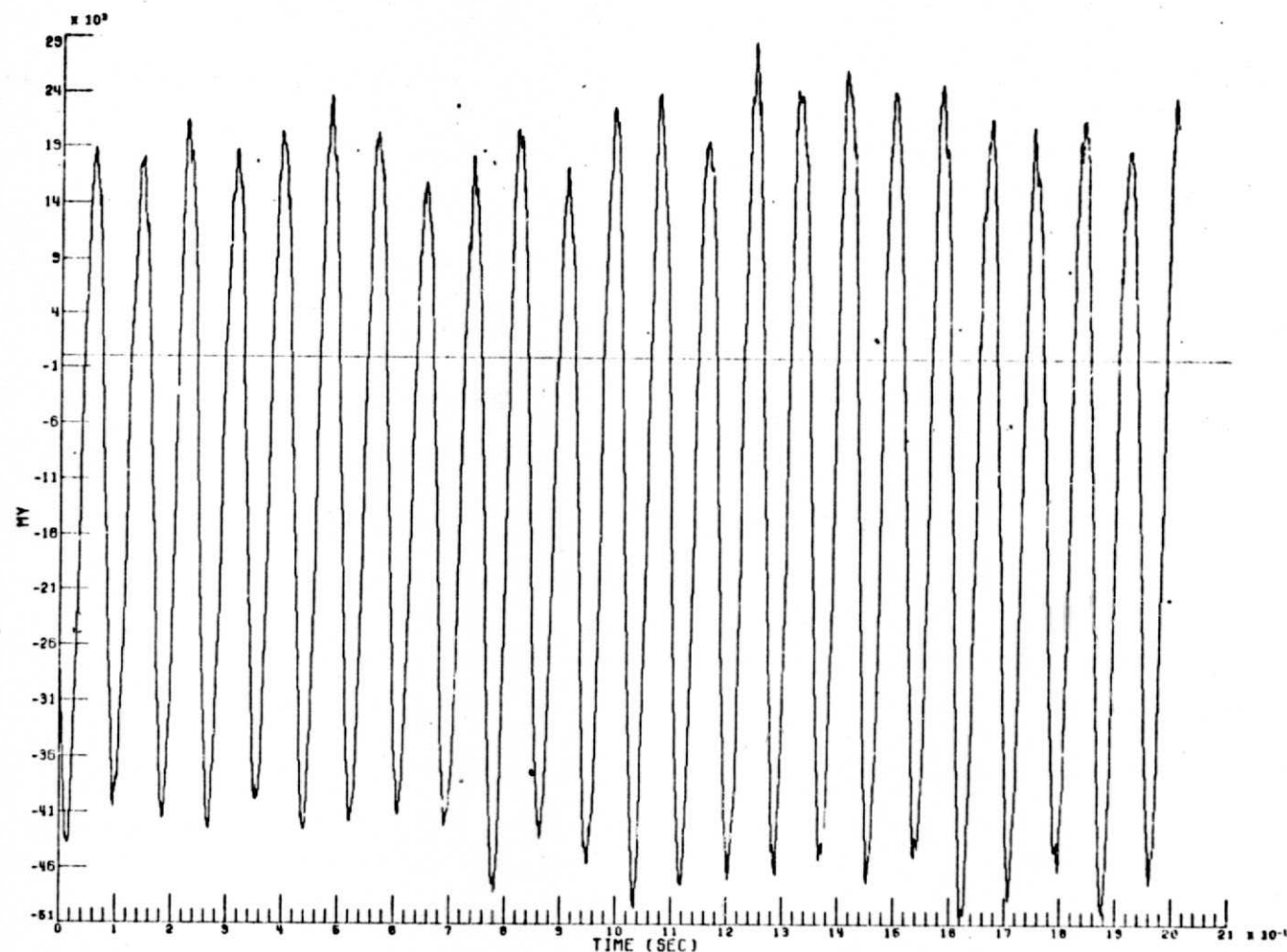
1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.5b. TC-1 Max POGO - MX PSD



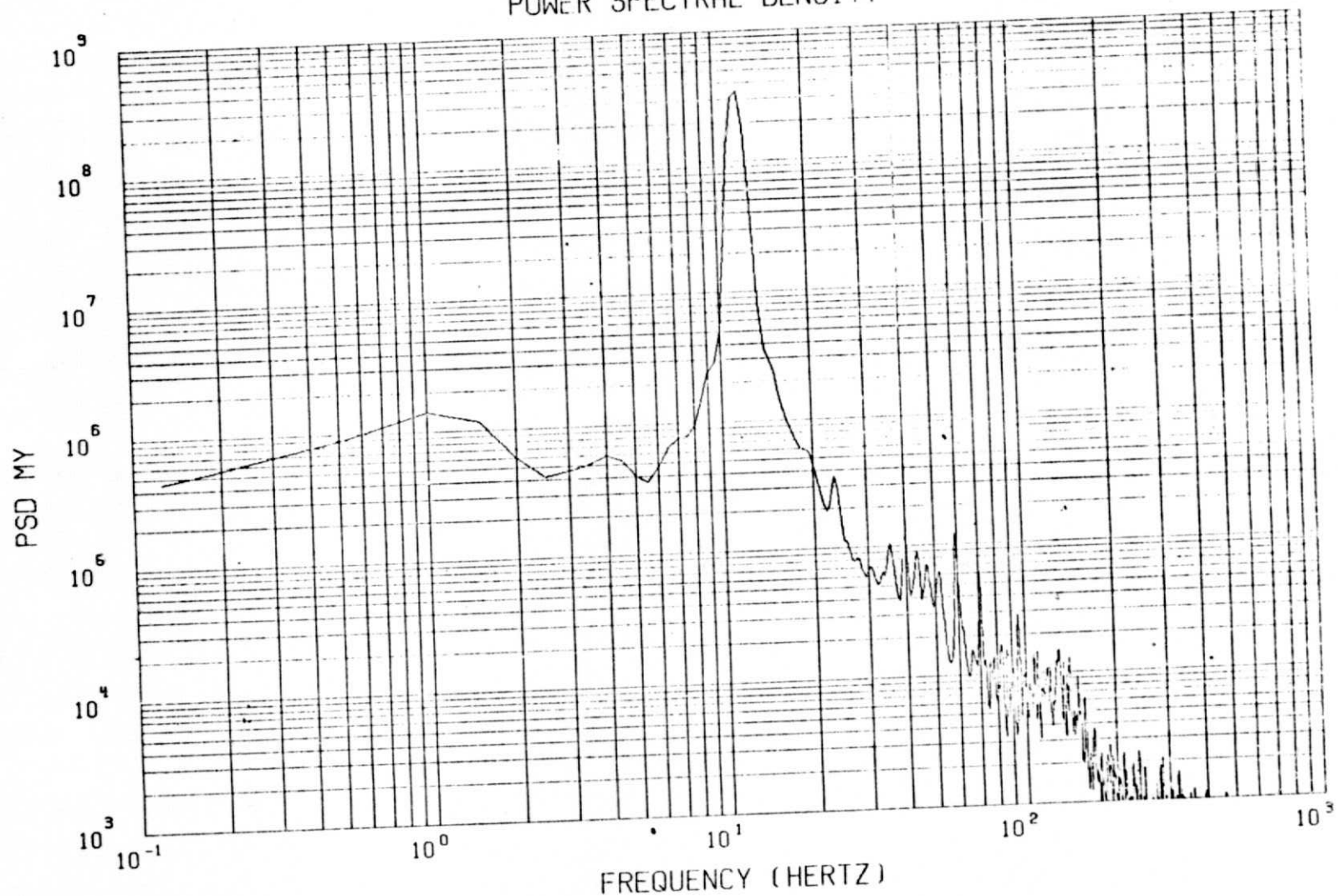
SERIAL NUMBER = 0

FRAME 33

2054 INPUT DATA POINTS

Figure 1.6a. TC-1 Max POGO - MY

POWER SPECTRAL DENSITY



FRAME 40

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

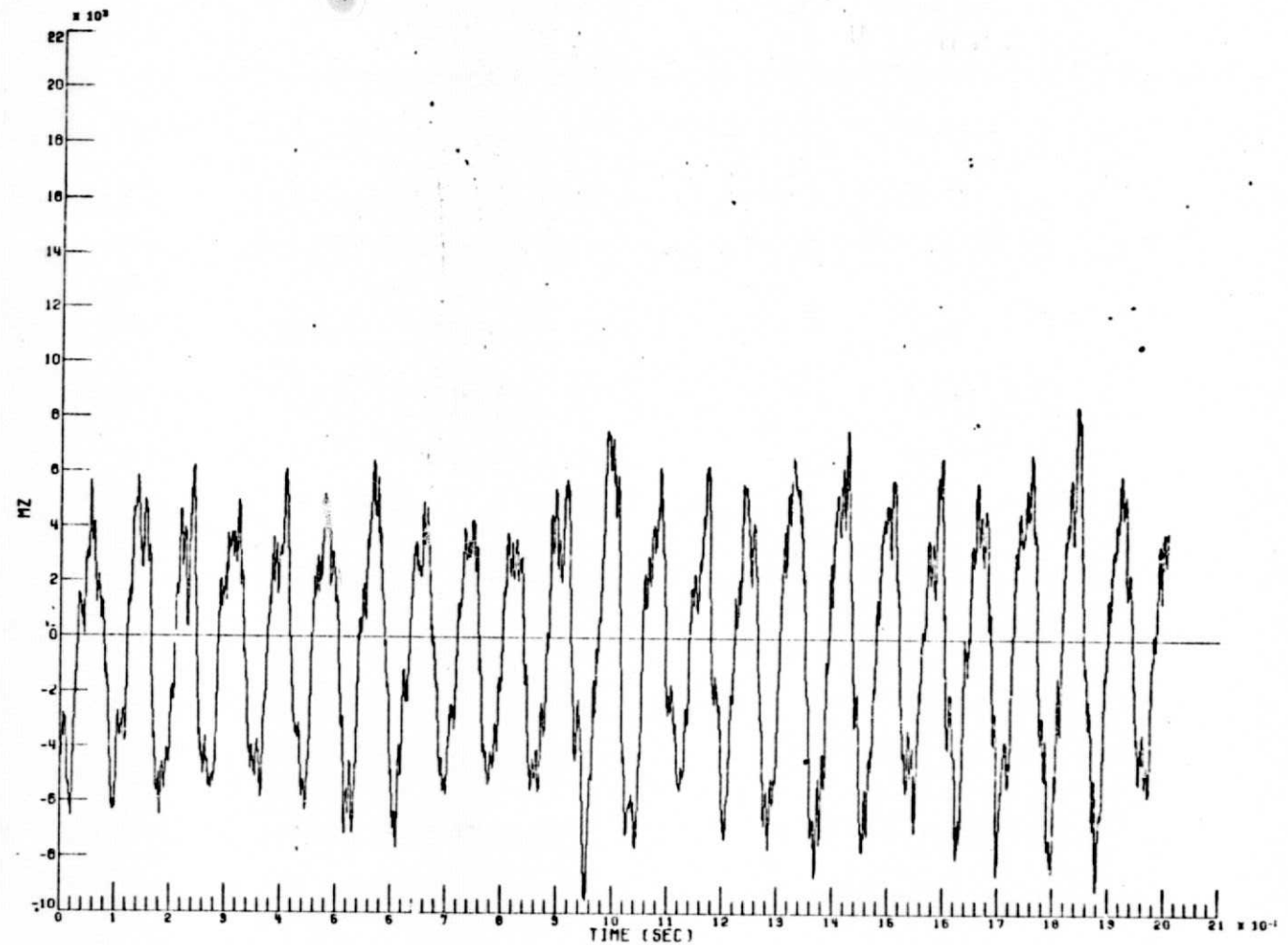
1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.6b. TC-1 Max POGO - MY PSD



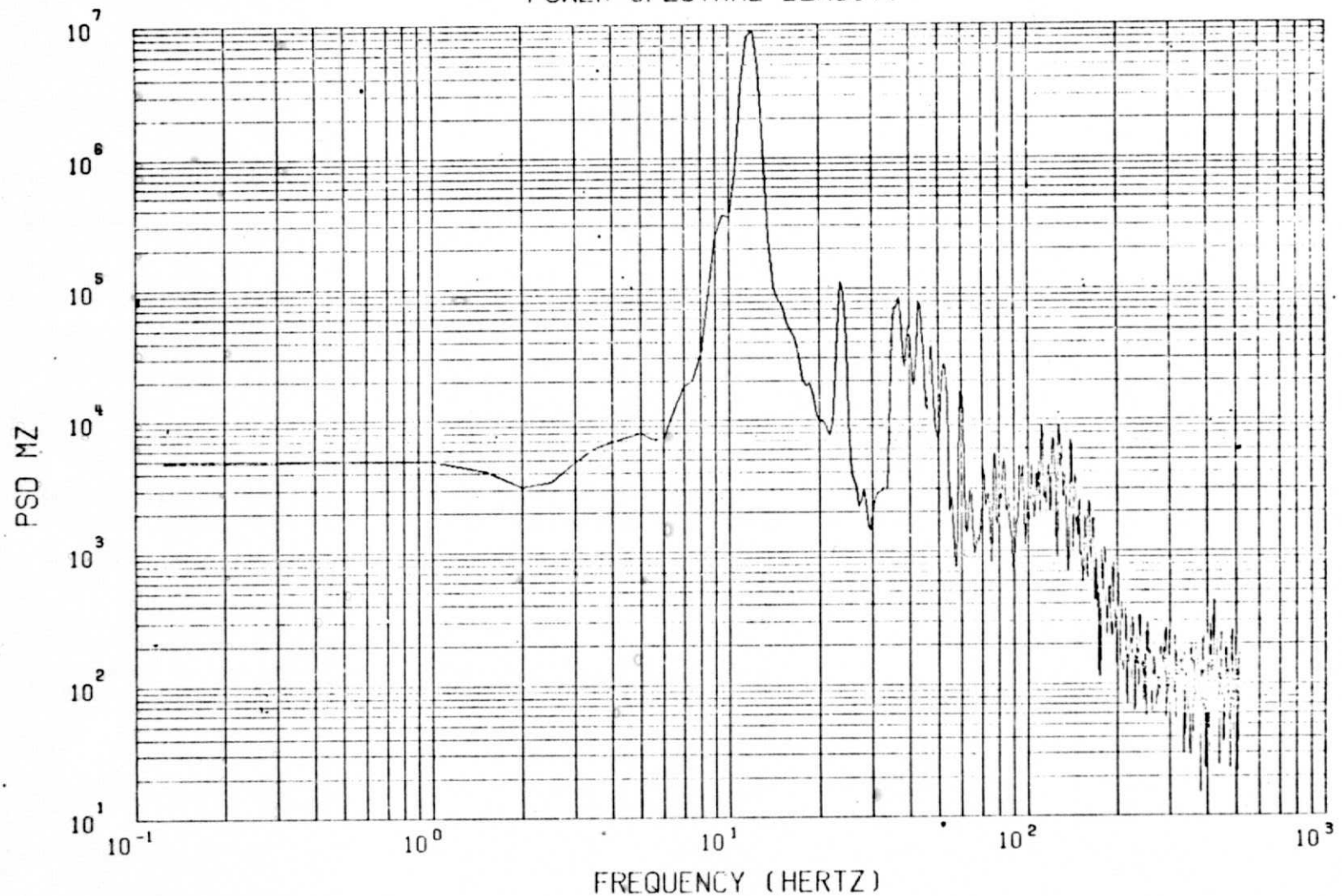
SERIAL NUMBER = 0

FRAME 47

2054 INPUT DATA POINTS

Figure 1.7a. TC-1 Max POGO - MZ

POWER SPECTRAL DENSITY



FRAME 48

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

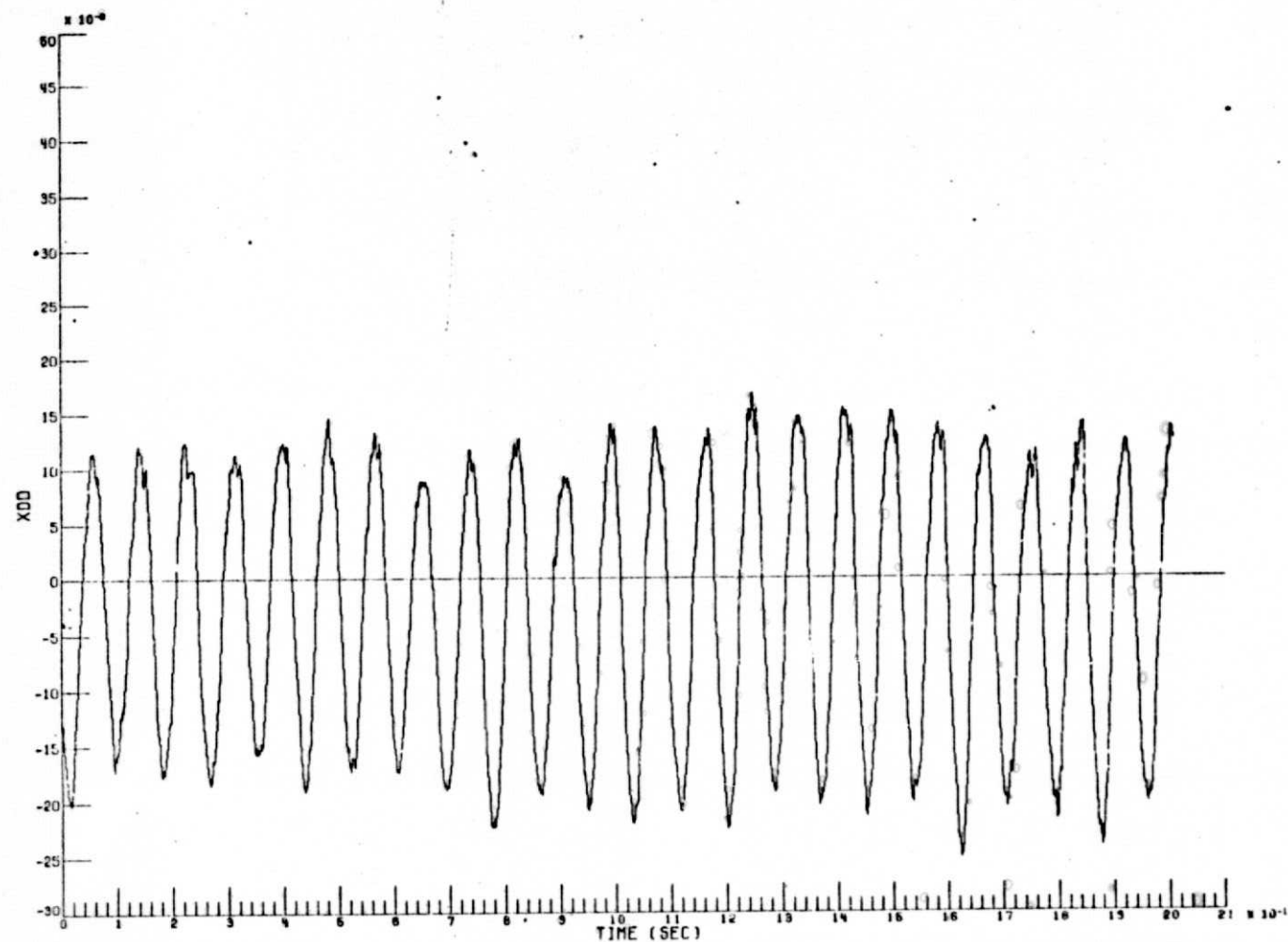
1025 POWER POINTS PLOTTED

ALGORITHM:

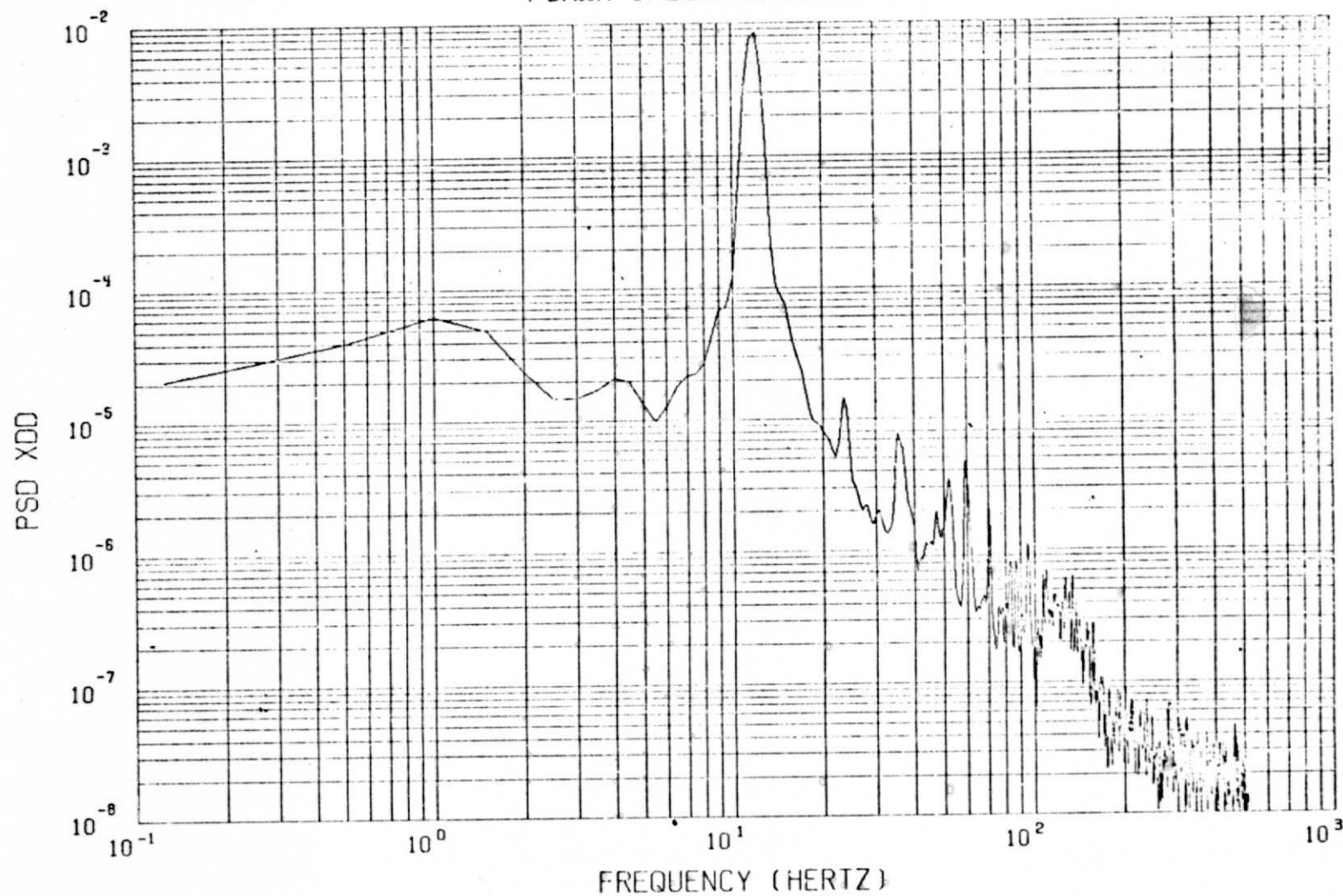
FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.7b. TC-1 Max POGO - MZ PSD

Figure 1.8a. TC-1 Max POGO - $\ddot{X}$ Lander c.g.

POWER SPECTRAL DENSITY



FRAME 56

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

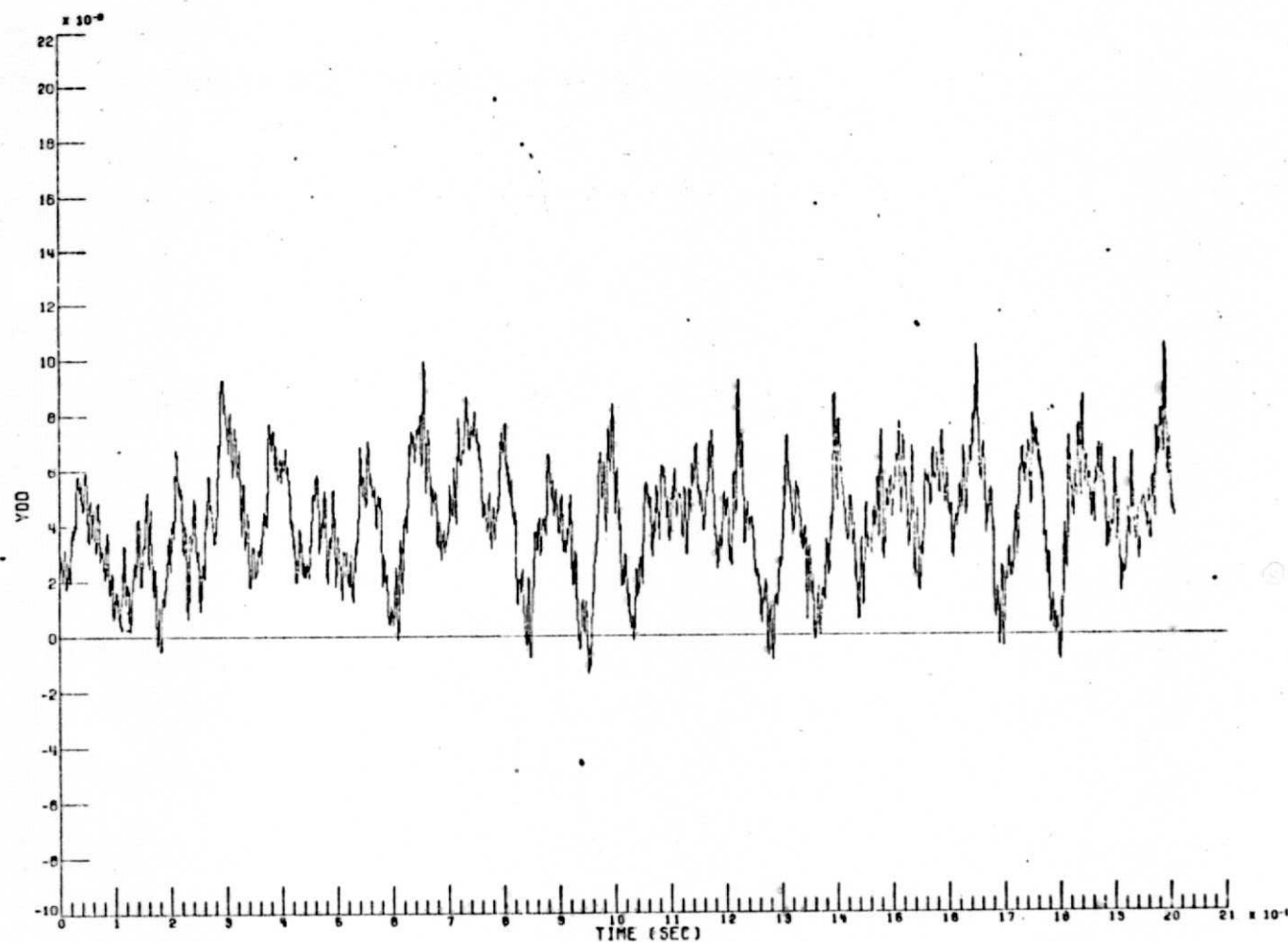
1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.8b. TC-1 Max POGO - Lander c.g. $\ddot{X}$ PSD



SERIAL NUMBER = 0

FRAME 63

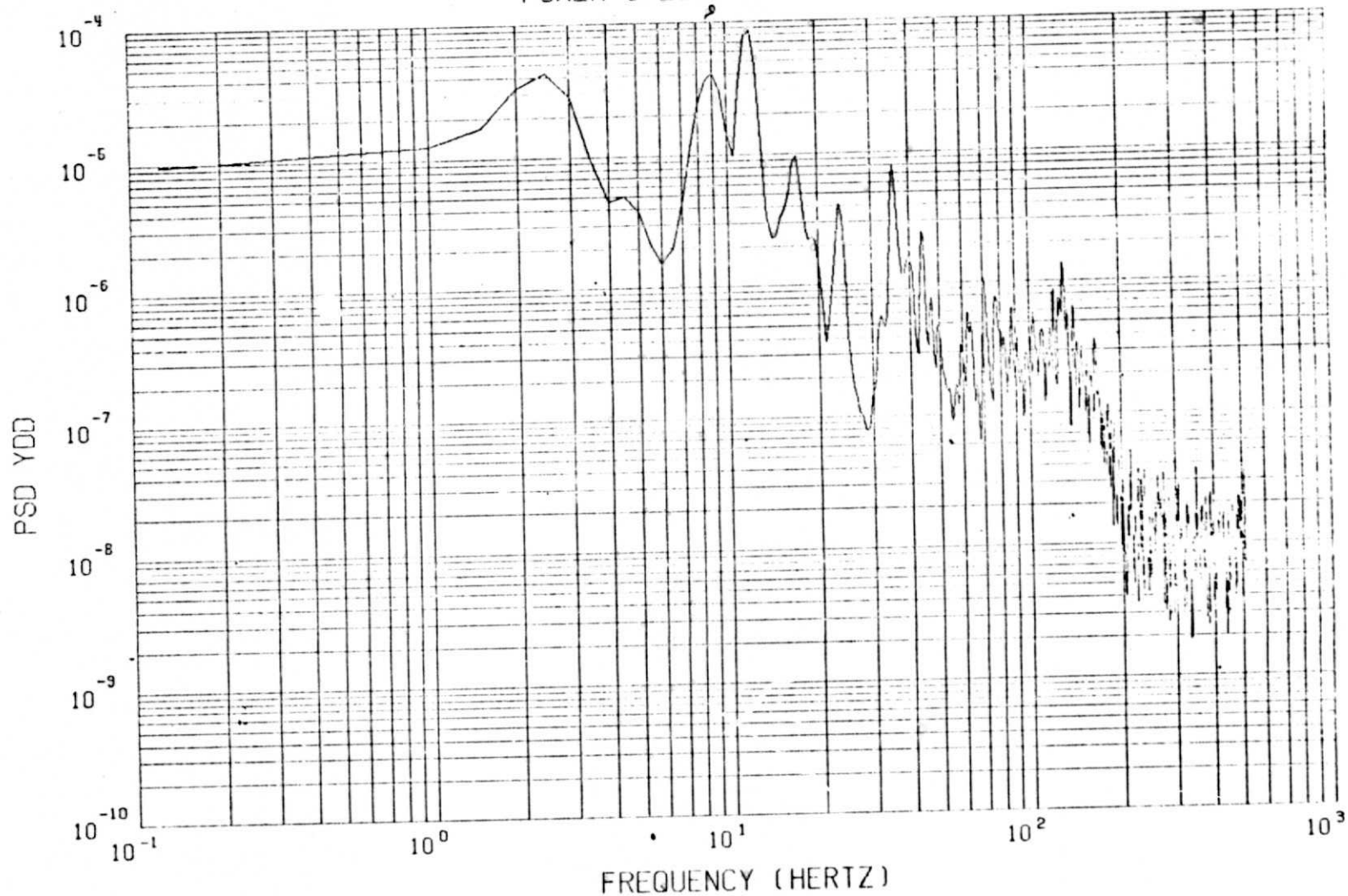
2054 INPUT DATA POINTS

Figure 1.9a. TC-1 Max POGO - Lander c.g. $\dot{Y}$

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 64

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.9b. TC-1 Max POGO - Lander c.g. Y PSD

1.22

SERIAL NUMBER = 0
FRAME 71
2054 INPUT DATA POINTS

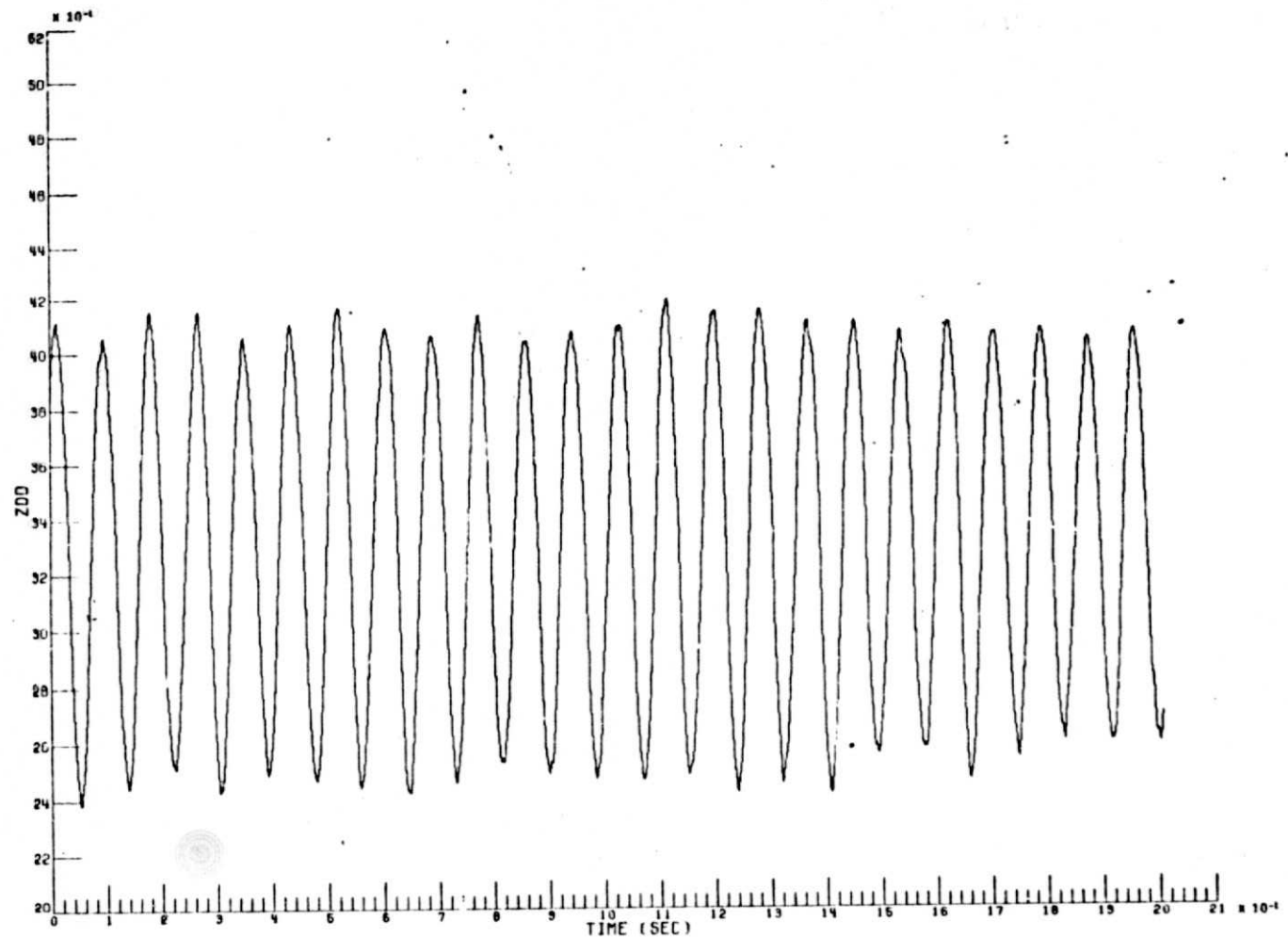
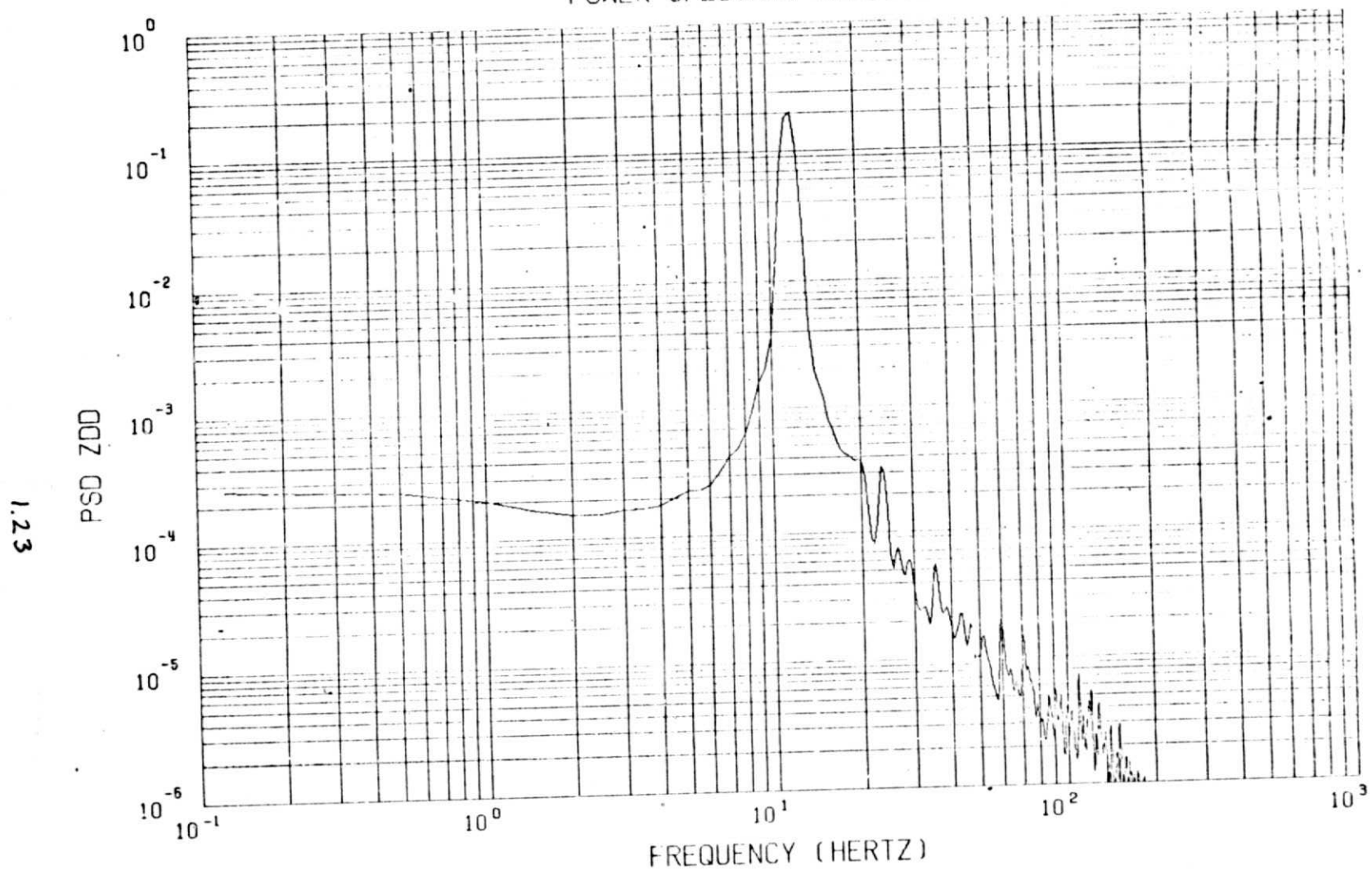


Figure 1.10a. TC-1 Max POGO - Lander c.g. Z

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 72

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.10b. TC-1 Max POGO - Lander c.g. Z PSD

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

1.24

SERIAL NUMBER = 0
FRAME 79
2054 INPUT DATA POINTS

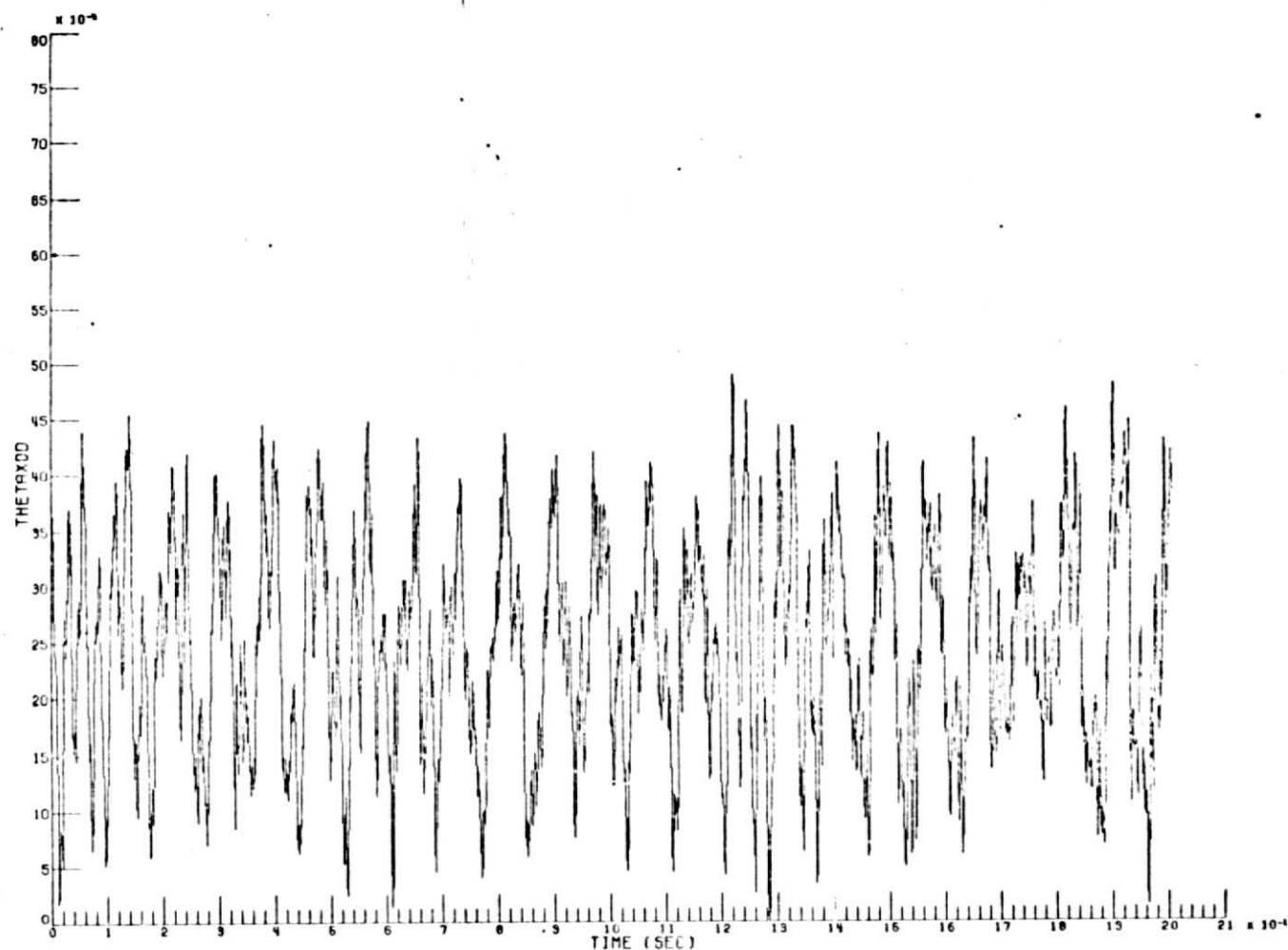
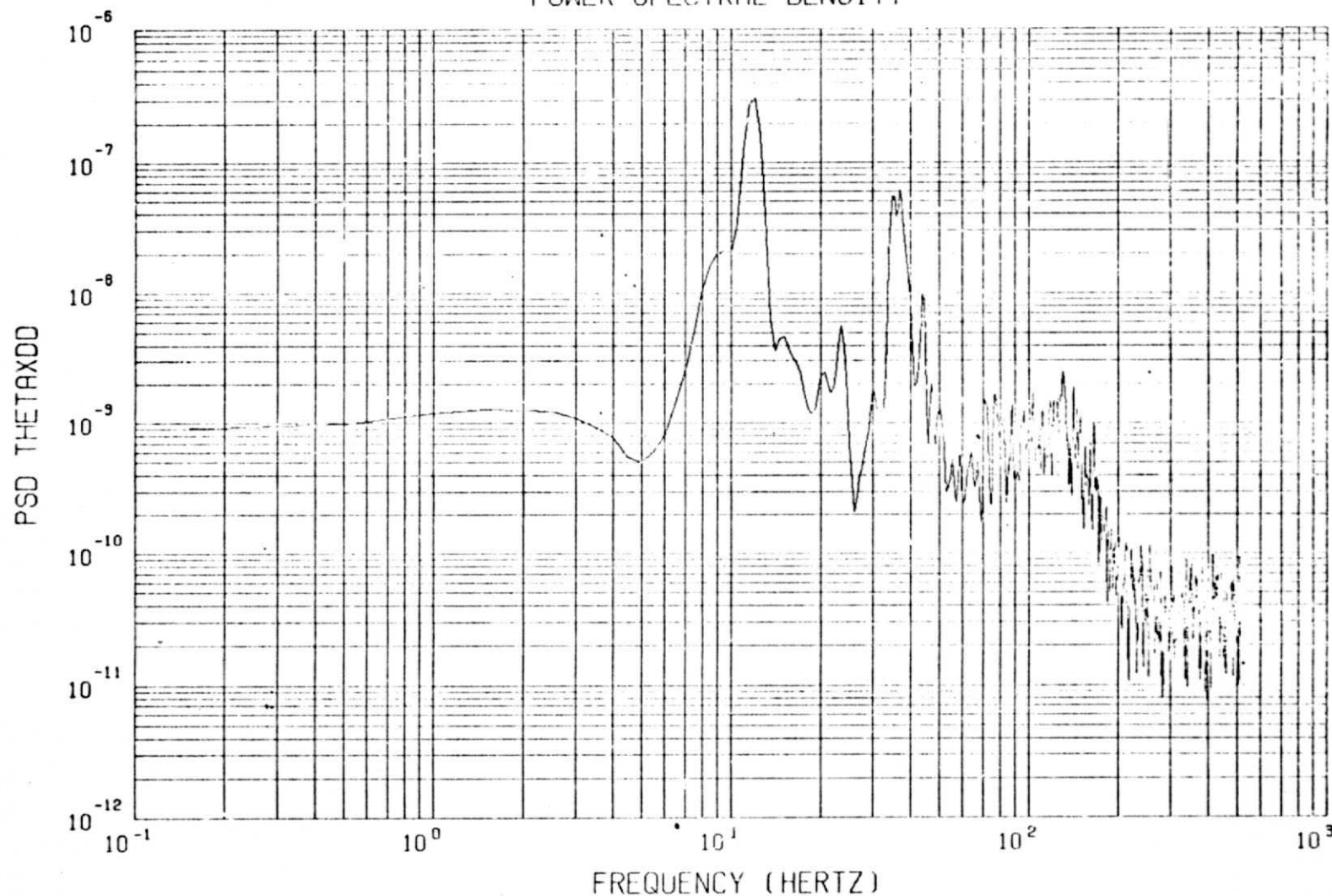


Figure 1.11a. TC-1 Max POGO - Lander c.g. θ_X

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 80

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.11b. TC-1 Max POGO - Lander c.g. $\ddot{\theta}_X$ PSD

1.12

SERIAL NUMBER = 0
FRAME 87
2054 INPUT DATA POINTS

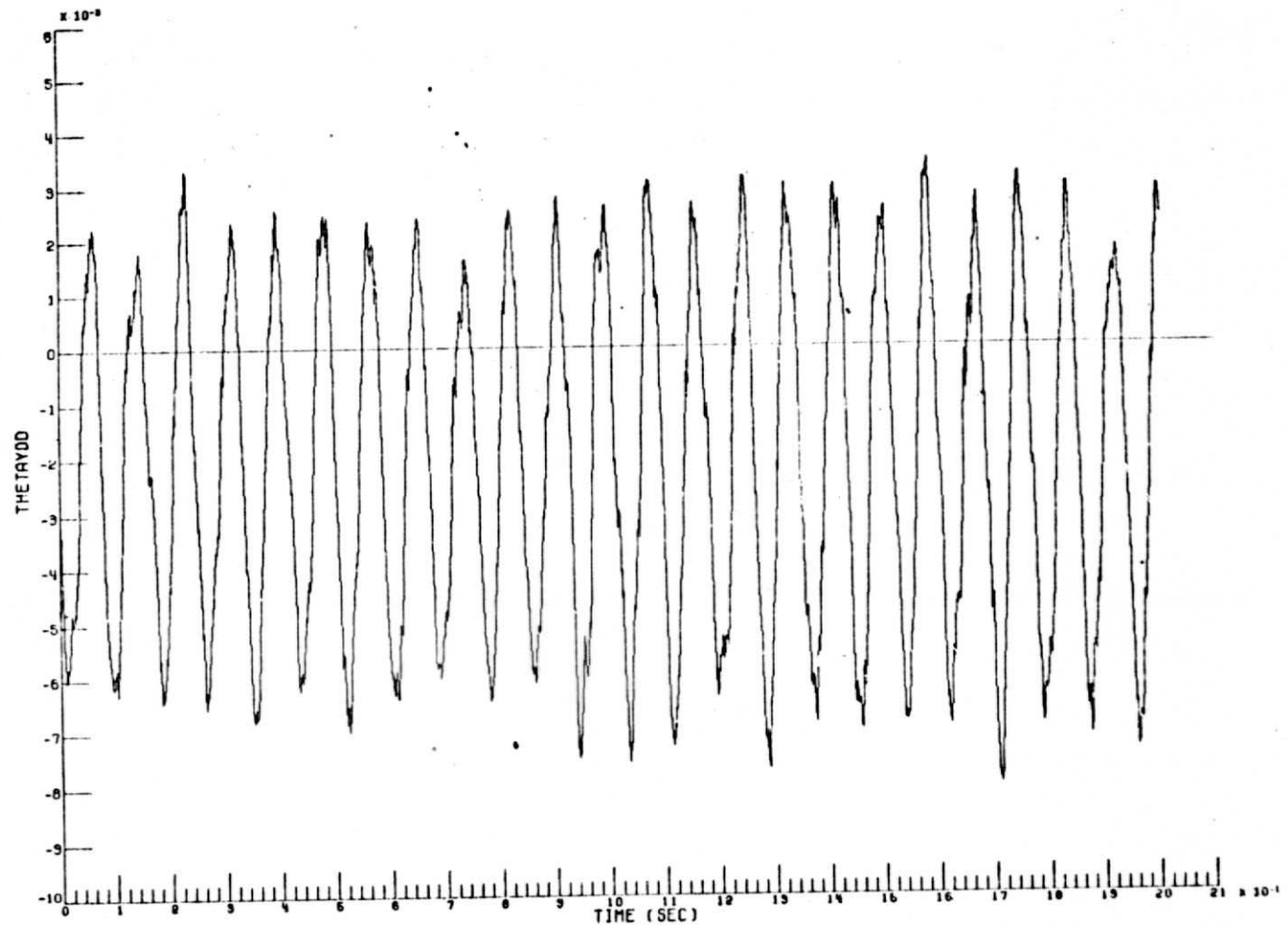
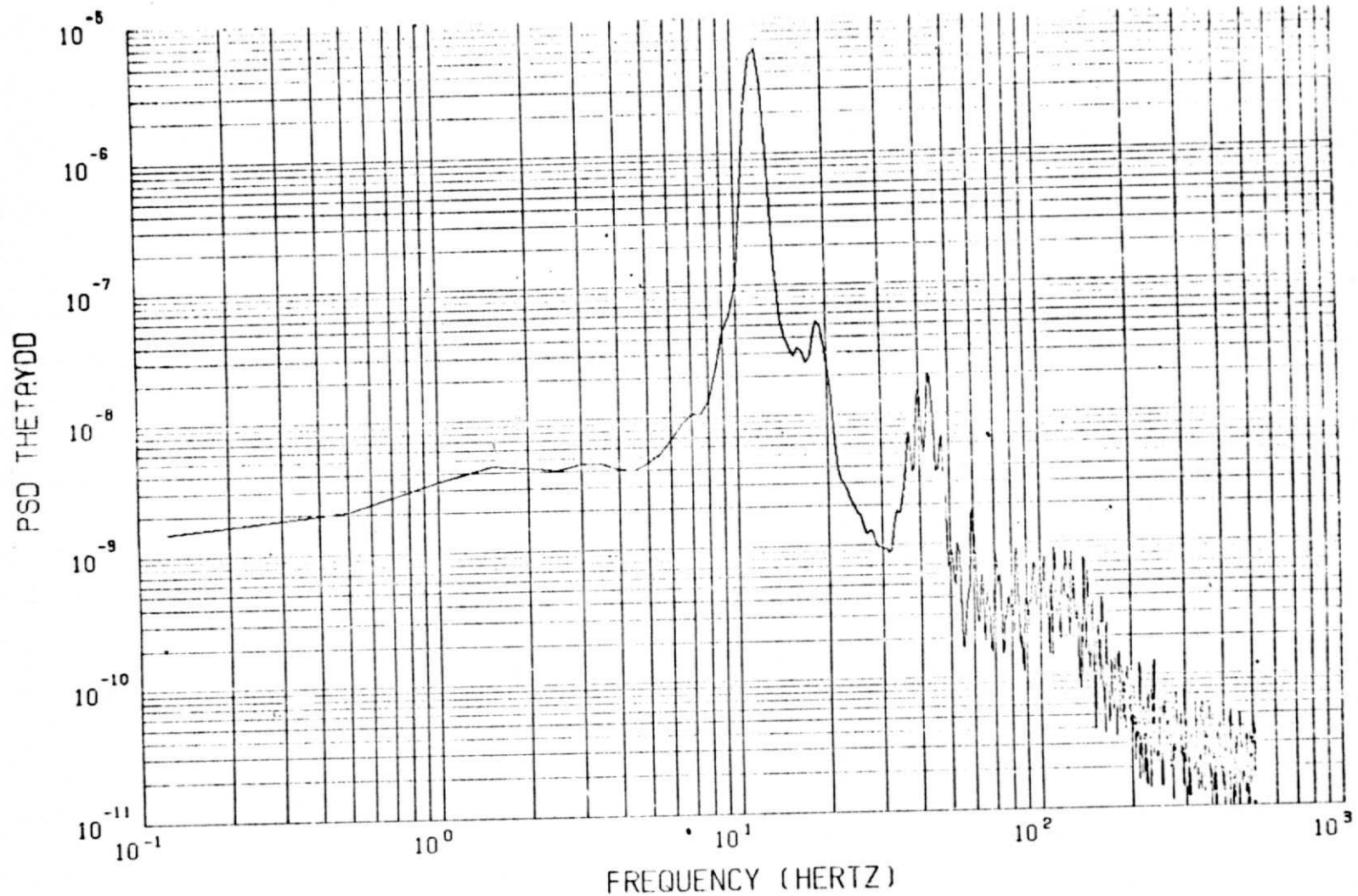


Figure 1.12a - TC-1 Max POGO - Lander cg. - $\ddot{\theta}_y$

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

POWER SPECTRAL DENSITY



FRAME 88

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.12b. TC-1 Max POGO - Lander c.g. $\ddot{\theta}_Y$ PSD

VDS DATA (LRC-2) POGO

13:51:58 - 13:52:00

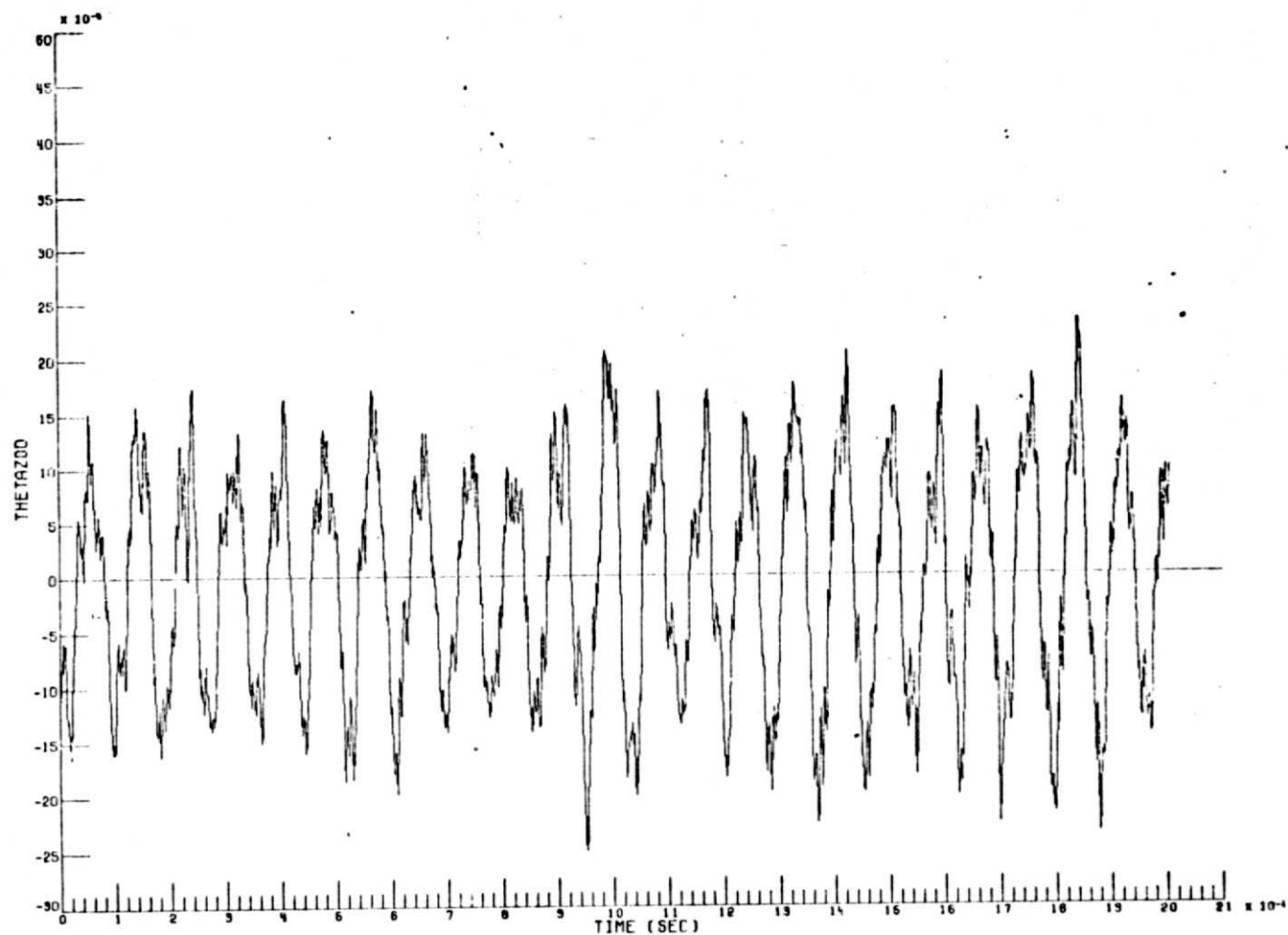
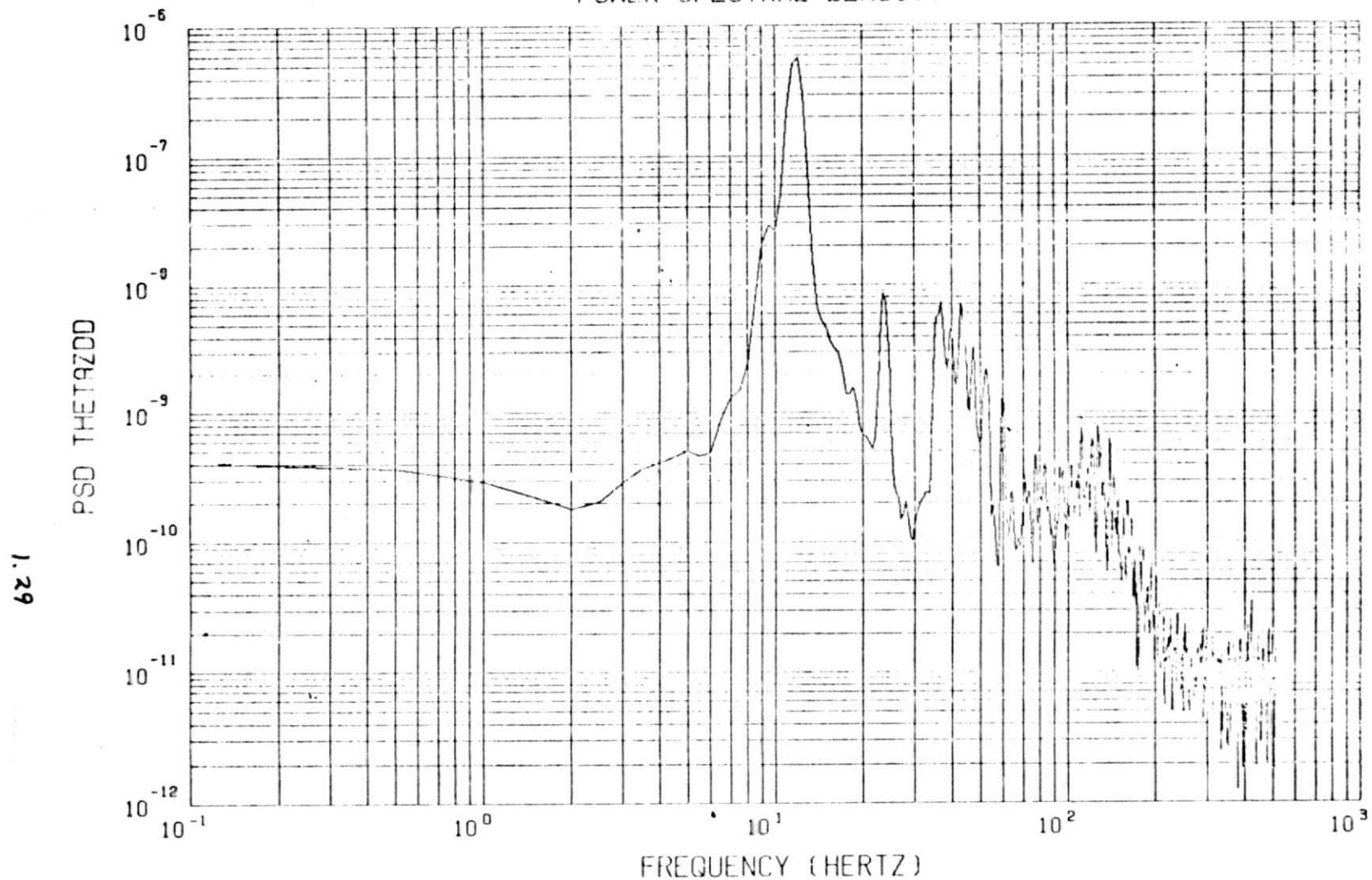


Figure 1.23a. TC-1 Max POGO - Lander c.g. θ_Z

POWER SPECTRAL DENSITY



FRAME 96

SERIAL NUMBER = 0

DELTA T = .00097

DELTA F = 5×10^{-1}

2054 INPUT DATA POINTS

1025 POWER POINTS PLOTTED

ALGORITHM:

FREQUENCY DOMAIN BLACKMAN-TUKEY

WITH PARZEN AUTOCORRELATION WINDOW OVER 1025 LAGS

Figure 1.13b. TC-1 Max POGO - Lander c.g. θ_z PSD